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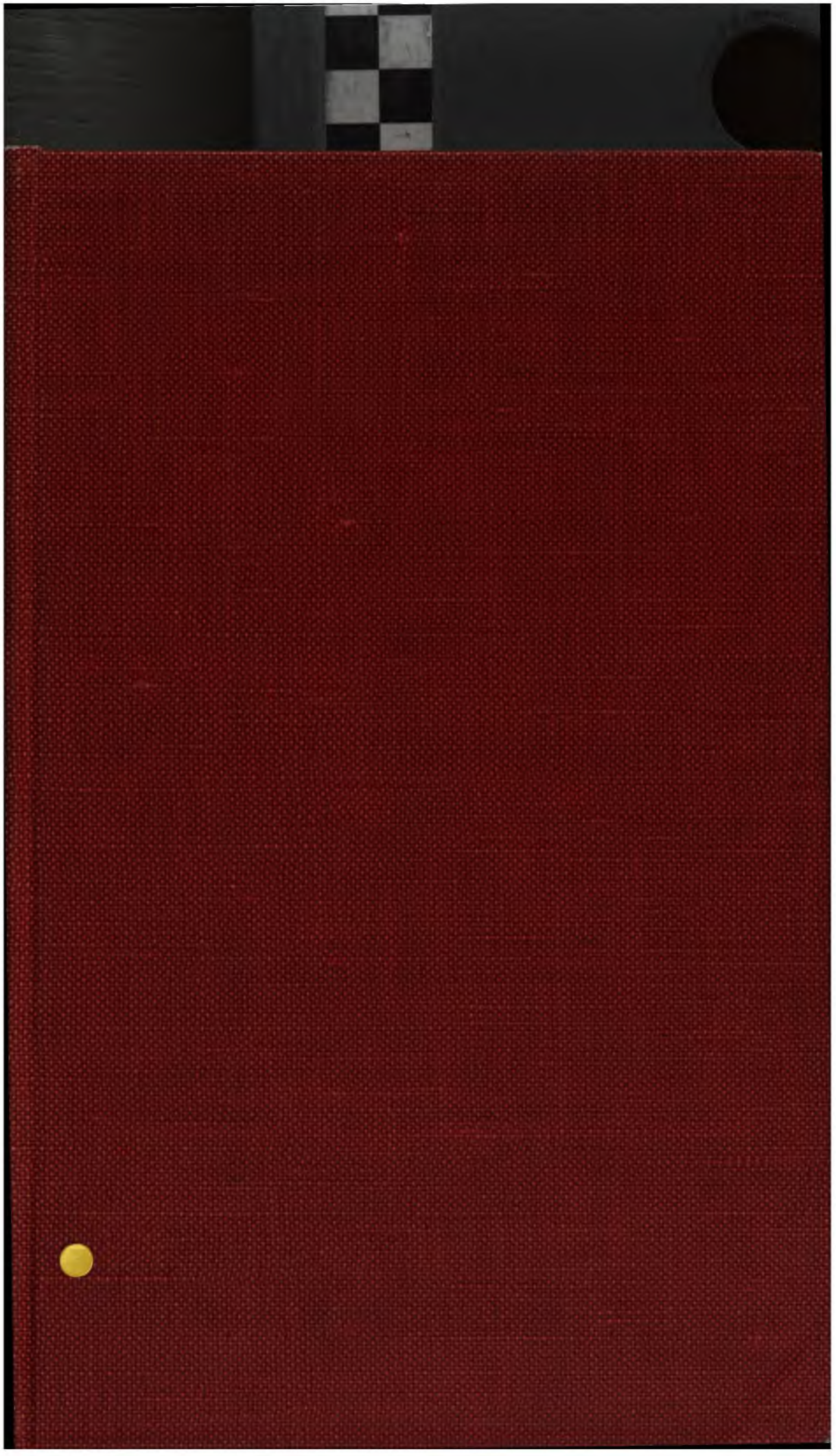

1912-10488

Geological Survey of New Zealand.

JAMES HECTOR, M.D., F.R.S.,
DIRECTOR.

REPORTS

OF

GEOLOGICAL EXPLORATIONS

DURING 1871-72,

WITH MAPS AND SECTIONS.

PUBLISHED BY COMMAND.

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ERRATA.

DR. HAAST'S Report on the Malvern Hills was unfortunately printed off without thorough revision, so that many press errors occur in it. The more important only of these are noted in the following errata :—

Page 6, line 15, instead of "brachopods" read "brachiopods."
" 6, " 30, " "Tœnipteris" read "Tæniopteris."
" 18, " 2, " "Backwood" read "Rockwood."
" 22, " 20, " "series. The" read "series, the."
" 26, " 23, " "position" read "portion."
" 27, " 36, " "have been" read "have not been."
" 28, " 15, " "basin" read "basic."
" 29, " 33, " "septari, like" read "septaria-like."
" 30, " 22, " "glaceconitic" read "glauconitic."
" 32, " 11, " "feet" read "miles."
" 36, " 35, " "Wales. I" read "Wales, I."
" 41, " 3, " "Tower" read "lower."
" 41, " 29, " "main seam" read "Big seam."
" 47, " 12, " "overlying" read "underlying."
" 47, " 14, " "bore" read "base."
" 49, " 23, " "Weather" read "Wether."
" 49, " 26, " "them" read "it."
" 54, " 18, " "Russia" read "Prussia."
" 57, " 17, " "level, free" read "level free."
" 60, " 4, " "porphyry, conglomerate" read "porphyry-conglomerate."
" 65, " 12, " "continuous" read "continues."
" 74, " 28, omit "are imbedded."
" 76, " 5, instead of "effected" read "affected."
" 76, " 19, before "I could" insert "as;" and in the same line, after "observe" insert "it."
" 81, " 37, instead of "anthracite" read "anthracitic."
" 85, " 20, " "their" read "very."
" 85, " 27, " "noapyrites" read "iron pyrites."
" 85, " 35, " "this" read "a."
" 86, " 1, " "this" read "the."
" 86, " 23, " "ullular" read "cellular."
" 87, " 15, " "dead" read "thick."
" 87, " 32, " "would" read "could."
" 103, " 4 from bottom, for "north-east and south-west" read "north-west and south-east."
" 110, " 11 from top, *dele* "at Moke Creek."
" 133, " 3 " for "South" read "North."
" 181, top line, for "Imaka" read "Oweka."
" 183, line 8 from top, *dele* "Marlborough; Mt. Cookson."
" 183, " 19 " "Lyndon."
" 184, lines 17 and 18 from top, *dele* "Black Birch Creek" and "(Upper series of Mt. Brown.)"
" 184, line 6 from bottom, *dele* "Culverden, Nelson."

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GEOLOGICAL REPORTS.

REPORT ON THE GEOLOGY OF THE MALVERN HILLS, CANTERBURY.

BY JULIUS HAAST, Ph.D., F.R.S.

25th October, 1871.

I. Area and Surface Features.

The Malvern Hills consist of an assemblage of mountains and hills situated between the Rakaia and Waimakariri rivers, the south eastern base of which is situated about 30 miles in a westerly direction from Christchurch. They cover an area of about 180 miles, being on the average 13 to 14 miles broad and long, and are connected by a low wooded saddle with the Thirteen Mile Bush Range, a portion of that great longitudinal mountain chain which runs in a north-east and south-west direction through the Province of Canterbury.

The lowest point of this district above the level of the sea is 770 feet at the entrance of the river Wakaepa or main branch of the river Selwyn into the plains, whilst its highest elevation does not attain an altitude of 4000 feet.

The structure and forms of the hills and mountains of which this interesting zone is composed, are as diversified as their lithological character. Whilst the main branch of the Selwyn, the Wakaepa river, has its own sources in the Thirteen Mile Bush range dividing the Malvern Hills into two nearly equal parts, two other branches the Hawkins in the north and the Hororata in the south, have their sources in the Malvern Hills proper, but form the boundaries of the ranges towards the Canterbury plains in their eastern portion. As will be seen in the following pages, the physical features of the mountains are in a great measure dependent upon the nature of the rocks of which they are built up, and the physical agencies to which they have been subjected. Thus the westerly portion, consisting almost entirely of palæozoic sedimentary beds, and having undergone abrasion to a considerable extent by the action of the enormous post

pliocene glacers, shows conical forms, the causes of which can in every instance be traced to the occurrence of hard sandstone or chertose beds, having resisted the powerful action of the ice plough once at work here, more effectually than the less durable shales and slates which have been equally subjected to it.

More towards the centre quartziferous porphyries show serrated and turret like features, of which Rocky peak and Rocky ridge near Rockwood, are fine specimens, whilst the basic amygdaloids which are not so well able to resist the influence of the atmospherilies have assumed more rounded dome like forms, of which Round-top Hill, above the Point Station is a good example.

The next rocks in age, porphyry conglomerate, have also resisted very well the erosive action, but the brown coal beds lying upon them would have been greatly destroyed, had not in the first place a thick bed of shell sandstone or limestone, often consisting almost entirely of shells, formed a protective cover over them. This limestone generally forms a ridge running in the direction of the strike of the beds.

The next beds are generally of an incoherent nature, mostly arenaceous sands, which in their turn are protected by sheets of dolerite abutting on the Canterbury plains, forming a longitudinal ridge which gradually slopes towards the east and falling abruptly towards the west exhibits the nature of the loose deposits below these igneous rocks. Thus the characteristics of each group of rocks are well defined also in the orographical features of the whole zone.

The rivers and streams have cut deep channels through the ranges, first through the glacier and post pliocene alluvial deposits, and afterwards sometimes deep into the older rocks below them. As I shall show, when speaking of these youngest formations, they owe their origin to various causes, and consequently they exhibit different characteristics and often anomalous positions, which could not be understood except by having traced them to their origin in the centre of the Alps.

We thus find morainic accumulations and post pliocene alluvium generally in well terraced beds in many localities, often hiding the older rocks for considerable distances, and making geological examination a matter of difficulty.

The annexed table of altitudes will give an insight into the orographical features which the surface of the district under review exhibits.

Although the Thirteen Mile Bush range does not belong to the

Malvern Hills proper, I have included it in my map, as some of the outliers of unaltered and altered brown coal, which I examined during this survey, are situated on its northern and western flanks. As will be seen from the table of altitudes, it rises conspicuously above the lower ranges in front, and belongs to that first great eastern range, which from Tekoa, in the Nelson province, runs through the whole province of Canterbury under different names such as Puketeraki between the Hurunui and Waimakariri, Mount Torlesse and Thirteen Mile Bush range between the Waimakariri and Rakaia, Mount Hutt and Mount Somers range between the Rakaia and Ashburton, etc. These ranges, broken through by the Alpine torrential rivers, which flow in deep rocky gorges through them, have generally the form of longitudinal chains over which here and there rise, where peculiarly hard sandstone beds occur, well defined pyramidal peaks, of which Mount Torlesse is an instance, whilst the Thirteen Mile Bush exhibits well the longitudinal and more rounded characteristics.

With few exceptions, the whole district has undergone so much burning from the hands of the runholder, that the original forest of scrub vegetation has been destroyed and given way to native grasses. Only a few patches of forest, consisting mostly of smooth leaved beech, (*Fagus cliffordioides*) have been saved, but as they are extensively used for fencing purposes and firewood, they will soon disappear altogether. The sides of the Thirteen Mile Bush range, however, are still clothed with luxuriant forest vegetation, exclusively the *Fagus* mentioned above, which ascends to about 4600 to 4700 feet on the eastern sides, whilst the summit of the chain is mostly bare, consisting of sharp angular fragments of rock (shingle), between which an interesting and rich alpine vegetation flourishes, in some respects different from that of the central portion of our Alps. How varied this vegetation is, may be adduced from the fact that I collected here in 1861 nearly 200 species of plants of which about 40 were altogether new to science, whilst the greater portion were very rare.

II. Geological Formations.

The oldest beds of the district forming the greater portion of the Malvern Hills consist of young palæozoic sedimentary beds. Before treating of them more in detail, it will perhaps be useful to glance over the general geological structure of the ranges by which the Province of Canterbury and the County of Westland are traversed.

Going from east to west we pass through the same series of

rocks, consisting of sedimentary beds of a most varied character, alternating in almost endless succession, and continuing to the very summit of the Southern Alps, where they are succeeded by rocks of a more metamorphic nature, with which at their western slopes granitic and other plutonic rocks are associated. It thus appears that we have before us a portion of a huge anticlinal arrangement of which the western portion has disappeared, the eastern one only remaining.

Speaking more specially of the arrangement of the eastern portion we may describe it as a continuation of anticlinal arches and synclinal troughs,; but instead of finding the mountains to be formed by the arches and the valleys by the troughs, careful examination shows convincingly that exactly the reverse has taken place. Thus, to give only one instance, whilst the enormous mass of Mount Cook occupies a synclinal trough, the broad valley of the Godley river runs along an anticlinal arch.

The occurrence of such enormous changes by which the arches or mountains have been converted into deep valleys, and the troughs into high serrated mountains, will give us a faint idea of the amount of time which has elapsed and the enormous waste which has taken place before the Southern Alps assumed their present form. The general strike of these sedimentary beds is south west to north east, but varying considerably, sometimes even in short distances according to the numerous foldings and bends. The strata dip generally at high angles, and stand sometimes almost vertically, a south-east and north-west dip being the most usual.

As the greater portion of the beds consist of sandstones of nearly the same character, we may describe the Southern Alps as sandstone chains. In my notes of 3rd April, 1870, on the geology of the central portion of the Southern Alps, including Mount Cook, I have alluded to this fact and given some details of the succession of rocks as they occur there.* Alternating with the sandstones we find slates, shales, brecciated beds (graywacke), and conglomerates in almost endless succession, forming generally sharply defined strata. Here and there we observe inter-stratified with them diabasic beds, sometimes in the form of ashes, and by which the sedimentary beds in contact with them have undergone considerable changes so as to assume all the characteristics of chertose rocks. Small beds of limestone, generally in the form of marble of whitish tints, are sometimes intimately

* New Zealand Geological Survey Reports, 1871, p. 9.

associated with these eruptive rocks, whilst under all other conditions the absence of limestone is very striking, even rocks with a calcareous matrix being generally wanting.

Thus it is evident that we see before us the deposits of rivers falling into the palæozoic sea, and judging from the position and succession of the boulders of which the conglomerate beds are composed, we may conclude that a large continent or island existed to the east or south-east of New Zealand, of which probably the old sedimentary and semi-metamorphic rocks of the Chatham Islands are still a small remnant, whilst the mainland has long disappeared below the sea. We perceive, moreover, that according to the state of the rivers or the changes of the currents, the character of the deposits also changed, the pebble and conglomerate beds representing the immediate neighborhood of the mouths of the rivers, whilst the fine-grained sandstones represent the littoral zone, and the clay-slates, and shales those regions of the bottom of the palæozoic sea where only fine particles of ooze could be deposited.

The great scarcity of animal and vegetable remains in these rocks is very remarkable, and as we have no reason to believe that the sea was devoid of organic life, we must assume that in many instances other causes have been at work to destroy its record.

In order to explain more fully what I mean, I may point out that there are markings or obscure exuviæ of an Annelid in many of the shales which rocks consequently could have preserved to us those of Mollusks had they been abundant. I have found these identical fossils near the sources of the Rangitata and of the Rakaia, in the very heart of the Southern Alps, near the mouth of the Hurunui, on the East Coast, and in many localities in the Malvern Hills, whilst sandy shales with markings of fucoid plants, identical in character, are met with in many localities, such as the Gorge of the Ashley, on the southern base of Mount Cook, and in the Four Peak Range.

If we apply the latest deep sea researches and their inductions concerning the Mediterranean, as given by Dr. Carpenter, F.R.S., and Mr. J. Gwyn Jeffreys, F.R.S., in the proceedings of the Royal Society, Volume XIX, No. 125, to the physical conditions which might have prevailed in our palæozoic seas during the formation of the New Zealand strata under review, our difficulties under that head might be easily removed. We know that in our palæozoic strata there are beds of conglomerate of enormous thickness, the boulders of which they are composed showing that they must have been derived from ranges of

great lithological variety, and indicating that they were brought down by large rivers, whilst the general character of the whole strata associated with these conglomerates indicates clearly that they could only have been formed from the sediment of such rivers. Thus it is easily conceivable that one of the conditions might have existed which now prevails in the more central portion of the Mediterranean to the prejudice of the existence of animal life, namely, *turbidity of the bottom water*. Of course this might have been only one of the causes of this remarkable scarcity of animal life, but I need scarcely point out how very important it is to the geologist now to account for facts which before the deep sea dredgings now undertaken could only hypothetically be explained. However, in one locality, there is ample evidence that animal life was not missing by the occurence of fossiliferous beds on the western side of Mount Potts, Upper Rangitata, containing many brachopods and a few gasteropods. The principal shells are different species of spirifera; besides them there are species of Productus, Murchisonia, Euomphalus, Nucula (?), Orthis, and Orthoceras. Most of these shells, of which some broad winged Spirifers are very numerous, according to Professor M'Coy of Melbourne, are identical with Australian fossils, and are of lower carboniferous or upper devonian age.

During the progress of the preliminary geological survey of the Canterbury Province, I had no time to examine these interesting strata more minutely, which, I have no doubt, if carefully searched and followed in both directions, will lead to important results. What gives an additional interest to these beds is that hitherto I have not been able to find any others of the same character over the length and breadth of this Province. Other beds of equal importance occur in the Clent Hills, in which I gathered a rich harvest of fossil ferns, mostly Pecopteris, Tœnipteris, and Camptopteris which, according to Professor M'Coy, are of Jurassic age, identical with beds belonging to the New South Wales coal fields; and although I believed this Clent Hill series to be somewhat younger than the Spirifera beds, I demurred to this definition, owing to the fact that the position of the strata and the character of the rocks of which they are composed have quite a palæozoic facies.

Since then it has been shown, and as I think with conclusive evidence, that both fossiliferous strata, the Spirifera and Pecopteris beds occurring together in the New South Wales coal fields, are of the same age and alternate with each other. The occurrence of Tœniopteris,

which hitherto had been considered only of secondary age, seems to speak against a palæozoic origin; however, I may point out that the same objection was made to the Glossopteris in Australia, but which has by overwhelming evidence been shown to be also of palæozoic age. I do not think that the fragment of a leaf, however distinct, can unsettle all that stratigraphical geology has proved to be correct.

These Pecopteris beds are also well developed in the Malvern Hills, where they form the lowermost visible beds, and this brings us to examine more closely their general characteristics in that district.

From the southern slopes of Abner's Head to the northern slopes of the Snowy Peak Ranges, in a E.N.E. to W.S.W. direction, an anticlinal arrangement of the sedimentary beds exposes to our view the lowest visible strata of the whole series. They consist of shales often very carbonaceous, sometimes marly or micaceous, of gritty, generally tabular sandstones, mostly of light colors, and of conglomerates.

Owing to the curious fact that these beds are not so much jointed, or do not generally stand at such high angles as the overlying strata, and, moreover, the country where they occur being generally covered with post pliocene alluvium or morainic accumulations by which their true relations are mostly hidden, the first inference would be that they overlie the older-looking, more compact and jointed beds of which by far the greater portion of our Alpine Ranges are composed; and it is only by following them closely and investigating carefully their relations to the former, that their true position became clear.

I shall show in describing the accompanying sections in detail that the anticlinal in the south-western part of Flag Pole Hill is still perfect, whilst its southern is removed in the eastern, and its northern side in the western portion of the ranges. The matrix of some of these conglomerates is often so little binding that some of the beds appear almost as if they were of post pliocene age and origin.

From an examination into the position and size of the rolled fragments of rocks of which these conglomerate beds are composed, and from the fact that they generally get smaller towards the west, it is evident that they were deposited by huge torrents coming from the east, or more correctly stated from the south-east, descending either from a continent or large island, and entering here the palæozoic sea.

That the rocks forming this palæozoic land were of a very varied character, is easily ascertained in examining the nature of the beds of which these conglomerates are composed. During the progress of the

geological survey of the Canterbury Province, I have repeatedly had opportunities of doing so, and I have invariably collected specimens from the boulders and pebbles of which they are composed, so that I have been able to compare them with each other. I will also here enumerate some of the principal localities in which these rocks occur, as they fix an horizon from which further researches can be made. There is, in the first instance, the Malvern Hills conglomerate, to the strike of which I have previously alluded. It consists almost exclusively of well-rounded stones, of greenish and bluish fine-grained sandstone, from small pebbles a-fourth of an inch, to boulders three inches in diameter; generally, they have all the characteristics of true river shingle, but in a few localities they are flattened as if they had been subjected to the action of the surf. The sandstones of which these conglomerates are composed resemble in every respect those which form the beds overlying the conglomerates, and must have been of similar origin. The conglomerates contain, besides the sandstone boulders, a few pebbles of bluish or white quartz, and a few pieces of gneiss, generally appearing in the form of Protogene gneiss. The binding medium is quartz sand, often colored by peroxyde of iron, in which case each rolled stone is also coated by the same mineral. Conglomerate beds occupying the same position occur also on the south-eastern corner of Lake Coleridge, and in Mount Barker, a roche moutonneé lying at the head of that Lake, and of which I have given a description in my report on the head waters of the Rakaia, page 49. These latter beds consist only partly of sandstone pebbles, but contain a great variety of plutonic and metamorphic rocks, such as granite, gneiss, porphyry, quartzite and lydian stone, so that we must assume that they cannot be the deposits of the same river as that which brought the Malvern Hills conglomerate into the palæozoic sea. The nearest approach to the latter strata are beds found in the Clent Hills, as they also consist almost exclusively of sandstone pebbles, with a few pieces of gneiss amongst them, while the conglomerates in Pudding Valley and Mount Harper, near the Rangitata, and in the Four Peak Range, between the Orari and Opuha rivers, are identical with the Lake Coleridge beds.

Amongst other rocks, pebbles of a bright green porphyry, and of a peculiar bluish quartzite are common to them all, besides the fragments of granite, gneiss, and lydian stone.

It would be of great interest, and would facilitate the explanation and division of our older sedimentary strata if these beds could be

followed, so as to prove whether they are continuous, or at least to fix their position exactly over the whole of this portion of New Zealand, as I have traced them not only to Tekoa, a mountain on the northern bank of the Hurunui, in the Nelson Province; but, looking over my old field books, I find that the same conglomerates occur extensively between the Wairau and Awatere, in the Province of Marlborough, where I examined them as far back as August, 1859. And as a continuation of the Wairau rocks strikes across Cook's Straits, I have no doubt that the same conglomerate beds will also be found in the Northern Island.

I have compared carefully the Pecopteris occurring both in the Malvern and Clent Hills, and have found that they are identical, and at the same time quite distinct from the Polypodium Hochstetteri of secondary age, from the Northern Island. These extensive beds are therefore of the same age as those in New South Wales in which the fine coal seams occur, from which New Zealand receives at present its principal supply. They are consequently of great interest to us, and the question naturally arises whether they might not contain also in New Zealand coal seams of the same value. As previously stated, there are small layers or pockets of impure shales in the Malvern Hills, but no appearance of any coal seam.

During the summer of 1864 I searched carefully over both ranges, the Clent Hills and Mount Harper, but I was not able to find in the former anything except a few shaley seams of one or two inches in thickness, and thinning out rapidly, whilst amongst the gritty sandstones on the south-eastern flanks of Mount Harper larger beds of shales full of impressions of ferns occur, together with small patchy seams of a beautiful cannel coal. Large trunks of trees, the bark of which has been transformed into *culm*, are also enclosed in the sandstones and shales.

I followed these beds for several miles in the hope of being able to meet with such changes in them that they would favor the deposition of larger coal seams, but I found them thinning out and disappearing altogether before reaching the lake region between the Ashburton and Rangitata.*

And although I have since then never omitted when working amongst beds belonging to this formation to examine them for deposits of coal, I have hitherto not met with any success. Mr. Fooks, of this

* See Report of the Geological Survey of the Province of Canterbury, 1864. Page 4 and 5.

city has, however, informed me that the last heavy floods in the Clent Hills have exposed a seam of coal, but he was unabe to give me particulars; and I received a few weeks ago from Mr. C. F. Tripp, of the Orari Gorge, a specimen of the same kind of cannel coal, which was obtained in one of the rivers near his neighborhood. I have therefore not given up all hope that future research might give a more favorable result.

Amongst the strata which overlie the conglomerates, diabasic beds claim our attention next, they are inter-stratified with cherts, sandstones, and shales, and where lowest in the series in a few instances with conglomerates. Only in two localities they consist of a fine grained diabase, but generally they assume the character of a compact rock, resembling diabasic ashes or tufas. Some of these beds are one hundred feet, others only a few inches thick, and alternating repeatedly with sandstones or shales, which generally have undergone most remarkable changes by having been altered to hornstones and cherts, or to semi-metamorphic rocks of a more indistinct character. Some of the large diabasic layers, mostly of a green color, are still more intimately associated with cherts, by forming the bed rock in which kernel strings and pockets of chert are enclosed. In some other localities calcareous spar, or marble occurs also in small veins or strings between them. A few of these diabasic beds, where of great thickness, have sometimes the appearance and structure of serpentine.

There are in the Malvern Hills no amygdaloidal or variolitic diabases such as occur in many other localities over this Island, in similar positions; those in the district under review having always a more tufaceous character. Limestones, mostly in the form of marble of a whitish color, are also associated with them either lying, as in Frank's Knob, at their base, or, as in Four Point Range, and in a few other localities, between or alternating with them.

I was, however, unable to trace any continuity in these limestones, as they occur only in lenticular shapes, thinning out and disappearing, to appear after a few miles, and assume again large dimensions. The calcareous deposits in Frank's Knob are about 40 to 50 feet thick; they overlie conformably greenish, coarse, sandstones, and are at first bluish, finely stratified limestones of the thickness of 10 to 15 feet, changing into white compact marble for the next 20 or 25 feet; they are overlaid by large beds of diabasic rocks, by which, without doubt, the changes have been brought about, and with which chertose beds of great thickness and variety are associated; but in following the marbles

in a north-east and south-west direction they very soon disappear, whilst the overlying diabasic and chertose strata continue to Russell's Flat, and in the opposite direction across the Selwyn to Flag Pole Hill, and so on to the Rakaia. No marbles were found by me in Flag Pole Hill, but they appear again in the Four Point range, both on the southern and northern side; but also there without being continuous.

I may here observe that these diabasic beds in the Selwyn have been considered for a long time to consist of, or at least to contain copper ore, and that several companies bought the ground for the purpose of mining, but hitherto without results.

As before observed, the diabases of the Malvern Hills have a compact structure, and I may here add that the more granular varieties of the same rock occuring in the Nelson Province, have without doubt been erupted in the same geological period, and are of a like origin.

It is very striking that these rocks have such a large extension in our palæozoic beds, both vertical and horizontal, and that in this respect they closely resemble the diabases of the Hartz Mountains in Germany, where they are also interstratified in beds of considerable thickness, ranging from the lower devonian to the upper carboniferous period. Professor E. Kayser, of Berlin, has given an excellent monograph of these Hartz beds, in the journal of German Geological Society for 1869, which is so applicable to our own Malvern Hill beds, that in most instances, if we would substitute for the German names, such as Alrode, Lupbode, &c., our New Zealand names Selwyn, Flag Pole Hill, they would describe and figure perfectly well our own sections. This shows once more convincingly, that however far the distance may be which separate two localities on the globe, the same abysso-dynamic causes were at work to build up the solid crust of the earth, under the same conditions, everywhere in like manner.

Like the conglomerates, these diabasic beds occur in many localities all over this Province, but they are generally not so conspicuous as the chertose rocks, altered by contact with them, which often form turreted crests on the summit of the hills, or run up like walls on the mountain sides.

It would be impossible to give an enumeration of all the different sedimentary rocks as to composition, texture, and color, of which the thick beds of this young palæozoic zone is composed, but I may say that almost every variety of sandstones, shales, conglomerates and slates occurs, to which I shall again allude when treating of the different

sections, and when I shall have an opportunity to describe some of them more in detail.

Although the strata are so much disturbed, that very often at short intervals they assume a different strike and dip, no unconformity or faults of any consequence were observed by me, the beds presenting simply that appearance which strata, having been folded in such remarkable manner would assume; the more so, if we remember that they have suffered so considerably from denudation.

It is impossible to say, at least in the present state of our knowledge, when these sedimentary palæozoic beds appeared above the sea, and how long they remained above it under powerful atmospheric influences, being subjected at the same time to erosion by rivers or by the sea, but we can affirm with safety that this period was a long one, that during that time they were folded, crushed, and denuded to a remarkable extent, and there is sufficient evidence to shew that even the forms of the present main valleys were already indicated. Thus when the next period of disturbance occurred, the main configuration of this Island was already so far stretched out that the addition of new rocks made no considerable difference in its outlines.

The rocks next in age are of an igneous character, consisting of two main groups, of which the older belongs to the basic and the younger to the acidic sub-division.

We have no data from which we can judge when those rocks appeared, but there is sufficient evidence to shew that they broke through the palæozoic beds upon which they rest unconformably, after the latter had generally assumed their present positions and their surface had already been denuded and partly decomposed.

The basic portions of these rocks rise to the greatest altitude in Snowy Peak to nearly 3000 feet. They consist of Amygdaloids, which are traversed by numerous dykes of a more compact rock of the same character (Melaphyre). They are mostly of greenish tints, contain large quantities of green earth and geodes of Agate and Quartz; some veins are filled with calcareous spars.

The latter mineral has been, however, often removed by water charged with silica. forming in many instances, pseudo-morphous crystals, or their casts, having filled up the cavities between the now decomposed crystals of calcareous spars.

In the deep gorge of the Rakaia on the other hand, where a magnificent section of both series is exposed, we observe mostly rocks of reddish or brownish tinge, which are traversed by compact Melaphyres.

The former are sometimes of Amygdaloidal structure, but between them occur also brecciated or even agglomerated beds, which appear to contain well rounded boulders and pebbles; however, the whole is so well mixed and bound up together, having at the same time a vertical position, that except by making a most minute survey it is impossible to separate these beds from each other, which appear to have been formed in or near the channel of a sub-marine crater.

In some other localities which are also laid down in the Geological Map, the same rocks occur below the next or acidic rocks, which are closely associated with them and to which I shall allude in the description of the sections, but everywhere these basic rocks form the lowest beds, and have in their turn in many instances undergone great decomposition and denudation before these acidic rocks were erupted. I have purposely used as general designation for the whole basic series the expression Melaphyre, because it will at once distinguish the various beds of great divergency of structure belonging to this series, from the basaltic and doleritic rocks of a more recent age which form such an important feature in the younger beds of the same district. Owing to the circumstance that there is still a great deal of uncertainty in the nomenclature of these rocks, which can only be remedied by analyising them in connection with careful microscopic examination, I think that the name Melaphyre might for the present remain as designation for these and similar rocks in New Zealand of that age, until the necessary examinations can be made. I may here add that it is always of the greatest difficulty to name rocks of an igneous nature from hand specimens alone, without knowing their exact geological position, and as an illustration I wish to point to the discussion between Sir Roderick Murchison and Professor Gustave Rose in Berlin, as to the nomenclature of the igneous rocks collected during the progress of the Geological survey of Great Britain (see Murchison's Siluria, 3rd edition, 1859, page 567).

Amongst the rocks of this zone there are finely grained greenish black or brownish black lustrous rocks with conchoidal fracture answering the original definition of *Brogniart*; some resemble the Swedish trap rocks, others again have *dolerite* like appearance resembling those of the Thuringian Forest in Germany, and even in some specimens of the latter class Olivine is well visible. The Amygdaloids of the same series in many instances so closely resemble those of Oberstein, in Germany, and of other well-known localities in Europe, which have been well examined, and of which we possess careful

chemical analyses, that it is impossible to distinguish between them when comparing the hand specimens of New Zealand with those from Germany, of which the Canterbury Museum possesses a fine series.

Covering these basic rocks, or lying on their flanks, appear rocks of an acidic character, which for a long time have been considered to be quartzose porphyritic trachytes, although many of them have all the appearance and character of true quartziferous porphyries, while others cannot be distinguished from quartzose porphyritic trachytes of Transylvania and other localities on the Continent of Europe.

In my notes on the Geology of the Waipara, page 8, etc., I have referred to this subject, and since then, having had the opportunity to examine these beds more fully during the progress of the Survey of the Malvern Hills District, I am led to modify my views, and to assign to them a greater age than I was formerly induced to do. One of the principal reasons why I considered these acidic rocks of tertiary age was that even in the lowest beds of the tufas which repose on their slopes, and are intimately connected with them, the same species of dicotyledonous leaves are frequently met with, which are of such common occurrence in the shales of the Hunua coal field, as well as in Motupipi, the Selwyn, etc., and which, according to Professor Unger, might be considered to be of tertiary age. Again, receiving the chemical analysis of some of these rocks, which I published in my Progress Report of the Geological Survey of Canterbury, 1864, made by or under the direction of two of the most eminent chemists of Germany, they were designated as quartzose trachytes, always under the impression that they were of tertiary age, the more so as acidic rocks, having the same structure, and the same chemical constituents, and which are of Eocene tertiary age, occur in Transylvania and elsewhere.

During the progress of my labors in the Malvern Hills I have however convinced myself that these acidic rocks are intimately connected with the melaphyres, although, as before stated, they are younger.

The tufaceous and shaly beds, with small layers of porphyry conglomerate which overlie the quartziferous porphyries, and upon which the porphyry conglomerate proper reposes in some localities unconformably, are both of great thickness, but the brown coal formation following next is also many hundred feet thick before we arrive at the calcareous beds which contain saurian remains.

As I shall show further on, these conglomerates contain beside the

dicotyledonous leaves, some ferns and a few conifers; however, as the researches of Dr. Debay have shewn that the cretaceous rocks of Aix La Chapelle contain many dicotyledonous leaves, allied to still existing genera, the occurrence of similar forms belonging to the exogens does not altogether indicate a tertiary age. When describing the tufaceous beds reposing on the flanks of the palæozoic and igneous rocks, I shall return to the subject, but I may here observe that the absence of all truly secondary fossil mollusca, such as Belemnites, Ammonites, and other characteristic forms from the whole series is very striking, and has to be accounted for before I can admit a secondary age for these sediments, although they do contain Saurian remains.

Examining the mineralogical structure of the acidic rocks of which this zone in the Malvern Hills is composed, we find that one of their principal characteristics, both in the porphyries as in the pitch stones belonging to them, is the occurrence of crystals of garnets of the red variety called almandine, as well as grains of bluish translucent quartz, both of which are seldom absent, being enclosed in a felsitic matrix.

This series is most largely developed in several well defined peaks and ranges, such as High Peak, Phillips' Range, Rocky Range, Rocky Peak, Mount Misery, etc; also the lower portion of the Rakaia Gorge gives a capital insight into its characteristic features.

They overlie not only the palæozoic rocks, through which they have broken, but also the melaphyres on the partly decomposed surface of which they appear in many localities.

As will be seen in the Geological Map of the district, they have a longitudinal extension from west to east, dipping mostly towards the south, but have in some localities an anticlinal arrangement where they appear on both sides of the melaphyric centre. They rise to an altitude of 3019 feet in High Peak, the highest summit of the whole system, and the principal centre of eruption, but have suffered considerable denudation in that portion of the country now occupied by the broad valley of the Rakaia.

In their eastern portion in Mount Misery and Mount Pleasant, where they assume sometimes tabular forms, and are of great thickness, they overlie exclusively the palæozoic sedimentary rocks, but this contact is generally hidden by younger beds.

In the western ranges, however, this contact is clearly exposed in many beautiful sections showing that they repose either on the melaphyres, or often directly upon the sedimentary palæozoic rocks.

Following the contour of the former, they are often only 30 to 40

feet thick, as if they had been flowing in stream-like beds from fissures in the older sedimentary or basic rocks. When giving a description of the sections, I shall return to this subject at greater length, but I must not omit to mention here that they are accompanied by Pitch stones, which mark the lines by which they were erupted, or where they came in contact with other rocks, and thus that they were subject to the same rules as volcanic rocks of younger origin.

Most of the higher ranges such as Rocky Peak, High Peak, Mount Misery, consist of such rocks, which having, doubtless, flowed frem several centres, forming rounded or conical hills, have cooled in that form. Many of these rocks have a trachytic appearance, without doubt from partial decomposition, to which they have been subjected from numberless ages and which has affected them to a great depth. However, at some favorable localities, in deep gorges and landslips I was enabled to observe how this earthy appearance of the base gradually changes into a true felsitic structure. This gradation can be more easily seen in the different dykes of the same rock, which radiate from the small outlier east of Rocky Peak, and have filled up fissures in the palæozoic rocks. The selvage of these dykes assumes sometimes the structure of an imperfect Pitch-stone, but the sedimentary beds close to them have been very little affected, the only difference being that generally they break in smaller polyhedral fragments than the same rocks a few yards further distant.

The principal centre of eruption appears to have been at the head of Rockwood Creek, at the base of High Peak, forming vertical cliffs very difficult of access. Here a syenitic granite porphyry occurs, which, however, I was not able to find in situ; it is identical with the *Porphyre Granitoide* of French authors. Dufrenoy's description of this rock from Signon and Aix applies fully to our rock specimen, No. 348. It has been traced by him and Elie de Beaumont to change gradually into porphyry similar to that of High Peak, but never into granite. (*See Elie de Beaumont and Dufrenoy explication de la carte geologique de France, I.* 30). Similar rocks occur in the Thuringian Forest, also together with "*Felsitporphyr*," (*see Lehrbuch der Petrographie Zirkel, I.* 528), it contains quartz, Felspar, and Hornblende, the latter found sometimes in well-defined crystals, but mostly in scaley aggregations; the Felspar is white, and, without doubt, Oligoclas. Besides this beautiful rock there appear in this precipice some brecciated porphyrites, and others more or less laminated; also, in the so-called Rocky Ridge east of High Peak some of the porphy-

ries have a similar brecciated structure, through which other portions of a more felsitic character in the form of dykes appear. Although this in many cases may be only an appearance, and the effect of different states of cooling, or re-arrangement of the particles during the cooling, some of those dyke-like masses may nevertheless be real dykes which at various periods during the eruption, and, probably, submarine deposition of these rocks were ejected, and filled up fissures in the previously erupted rocks of the same description.

Where the porphyries repose directly upon the palæozoic sedimentary beds, or upon the Amygdaloids, at the junction they appear either as pitch stones or they have a more or less tufaceous character, just in the same manner as a lava stream of younger origin which is stony in the centre, but always scoriaceous or tufaceous at the bottom, where it reposes upon other rocks. There is, however, one locality in the Gorge of the Rakaia where true tufas, and even shales appear immediately below the porphyries, and of which I shall speak more fully when describing the sections of that district.

Besides the crystals which have, doubtless, been formed during the cooling of the rock, these porphyries enclose sometimes small pieces of slate and sandstones either angular or having their edges rounded. These enclosed pieces are generally quite unaltered, but I observed one piece of sandstone which was remarkably fritted.

On the line of eruption we always find a band of Pitch-stone which is, according to the size of the beds, of more or less thickness; generally it is a black or greenish black rock, vitreous and porphyritic, containing always red garnets and sometimes Olivine and glassy Felspar (Sanidine). In a few localities Pitch-stone of a lighter colour occurs mostly of whitish shades, but always indicating the contact line. Some of these porphyritic rocks are of great beauty and would form excellent material for public buildings or other ornamental purposes.

Another portion of this interesting porphyry zone is on the banks of the river Ashburton where it rises in Mount Somers to 5000 feet, and where it is associated with Amygdaloids and Melaphyres, which, also there, are of greater age than the acidic rocks.

Before we proceed to consider the next series of beds, I wish to pass the physical features of the country under review, and to state how it appeared before these next beds were deposited. A large submarine valley or basin, extending in the direction of what is now the broad valley of the Rakaia, existed, across which, almost at right angles, a high ridge of eruptive rocks stretched towards the Mount

Somers range. Another submarine valley is indicated towards E.N.E. by the main valley of the Selwyn, whilst the Backwood Ranges, Pullwool Peak, Mount Misery, on the right banks, the Cairn Range and Abner's Head on the left banks of the Selwyn formed the shores of the Cretaceo-tertiary ocean. An arm of the sea running inland between Mount Misery and the Cairn Range formed a small bay now Hill's Flat; we thus see that, as before observed, the orographical configuration of the country was so far the same as it is now—of course with the addition of the younger strata deposited afterwards in the lower regions.

As we have at present no means of fixing the period when the Melaphyres and the younger quartziferous porphyries appeared, we cannot ascertain when these rocks, without doubt of submarine origin, first came within the influence of tidal phenomena.

The lowest tufaceous beds do not contain fossils from which we could draw any inference as to age; there are some dicotyledonous leaves in the clay iron stones, but they are mostly too indistinct for identification—there are however. a few which can be recognised as belonging to the same species as those occurring in the brown coal beds, thus clearly indicating that the whole series has been deposited in the same geological period.

Pieces of dicotyledonous wood converted into clay iron ore also occur in the lower beds. Higher up in the series there are leaves of the same exogenous plants as well as remains of some conifers, of which I obtained the impression of a large araucarian cone and twigs belonging doubtless to the same division of pines which are still at present inhabitants of Australia. I also obtained a few fragments of ferns. In vain I searched for the remains of fossil mollusks in this division, but since I began this report Mr. James M'Ilraith, whilst looking in Surveyor's Gully for the outcrop of the brown coal bed, accidentally exposed a fossiliferous stratum, of calcareous sandstones about six feet thick forming a vertical wall near a small creek. I have paid a visit to the locality in question and found the bed to consist almost entirely of an agglomerate of large oyster shells with bluish sands above and below it, which in decomposing assume a brown rust colour. It was exceedingly difficult to obtain any complete specimen of the Ostrea, a large triangular species, thick, of a white colour and peculiar to this locality, as the whole mass was so cemented together that they would not separate. Besides this species I obtained Pholodomya, Pecten, Trigonia, Fistulana, Teredina, Cardium, or species closely

alied to them, the whole presenting the same facies as the fossiliferous layers above the brown coal series. This Ostrea bed is situated about 200 feet below the brown coal measures, and is covered and separated from them by Porphyry conglomerate.

Looking at the formation of the whole series, it appears that after a time the older sedimentary strata, together with the eruptive rocks, came within the power of the waves, and were so extensively destroyed as to form the material for large beds, which in some localities are several thousand feet in thickness. These latter beds were, however, of a local formation, because with one exception, to which I shall allude presently, they all were deposited in the neighbourhood. Beginning at the Gorge of the Rakaia, we thus find that all the conglomerates are derived from the Melaphyres and Quartziferous Porphyries upon which they repose. The same conglomerate continues to the Cairn Range, where the pebbles of the Porphyry still form the principal material, but advancing gradually to the south-eastern slopes of Abner's Head the coarse sandstone of the Cairn Range replaces them, and only a few specimens of the rocks from the westerly eruptive region attest that the direction of the currents was towards the north east. Again on the slopes of the Cairn Range, consisting of Palæozoic sedimentary rocks, where the conglomerate beds are principally formed of pebbles of quartziferous porphyry, there are often layers consisting almost entirely of sandstones, as if the travelling of the Mount Misery material had been interrupted periodically in order to give time for the deposition of the more local debris. The most perfect section of these beds is on the northern bank of the Selwyn at the so-called Precipice Hill, to the examination of which I devoted some time, and to which I shall refer when speaking on this subject; but I may here add that the oldest beds in that locality contain only pebbles of chert and sandstone brought from the Four Point and Flag Pole Hill ranges, and that only occasionally a few very much decomposed fragments of Quartziferous Porphyry are amongst them; but gradually the latter rock becomes more and more conspicuous, till it excludes (at least in the Precipice section) the older sedimentary rocks for a time entirely.

The lowest beds in the series are mostly shaley and argillaceous, alternating with conglomerates. Some of the former would form fine material for fire proof pottery. Small detached pieces of coal occur between them, formed from drift wood; even large trees sometimes occur, showing by their present forms that they have been flattened to a considerable extent. They are mostly changed into bright coal, with

a dark brown streak (glance coal) ; some of these nests are so large that the ground has been bought for the purpose of testing it for the extraction of coal, but there is no where the least sign that workable seams could occur amongst these conglomerates, which form in this portion of the country everywhere the base of our newer sedimentary rocks.

Although there is generally no appearance of a break during the deposition of these beds throughout, there is nevertheless unconformity at one locality, which gives an insight into the manner in which these beds were deposited. They are developed most extensively on both sides of the Selwyn, and it would thus appear that very favorable conditions were here offered for a deposition of such material ; in fact, we observed that besides the debris from the eastern slopes of the front ranges a further supply of boulders, sand, and ooze was brought from the more westerly ranges into the small bay, in course of time lining both sides of its entrance. Thus, in examining the opposite slopes of Mount Misery and of the Cairn Range, we observe not only that the older beds of the conglomerate formation have a synclinal arrangement, but that they approach so closely that the Selwyn flows through a synclinal, the beds on both sides sloping towards the centre. When these beds had filled the channel between the two ranges they were partly denuded, after which the upper portion of the same formation was deposited upon them in a slightly unconformable position. These upper beds consist almost entirely of loosely cemented conglomerate and of quartzose sands, some of the former strata being several hundred feet thick, forming large walls, but they also fall slightly towards that portion of the valley of the Selwyn where Mount Misery and the Cairn Range form its boundary on both sides. Besides the debris brought by the tidal process, considerable addition was brought through that opening, the whole assuming here a fanlike arrangement towards the end of the deposition. That the conditions changed again and again is well exhibited by the repetition of the huge conglomerate beds which alternate for several thousand feet with loose deposits of a shaley or sandy nature.

Gradually the conglomerate beds, which are most largely developed in the middle of the series, disappear, and are replaced by coarse sandstones, the grains generally being cemented by hydrated oxyde of iron, or even sometimes resembling a limonite sandstone, in which dicotyledonous leaves are enclosed, apparently identical with those of the shales in the brown coal formation. This sandstone, generally forming thick

deposits, is the uppermost bed of the conglomerate series, or perhaps better stated, the lowest bed of the great brown coal formation of this part of New Zealand, and it is therefore a very important horizon for the discovery of the workable brown coal seams.

Before proceeding I wish, however, to mention that these conglomerates are sometimes very rich in beds or concretions of clay-iron-stone. The only locality where this ore is a compact brown Hematite is in the Gorge of the Rakaia. Whilst in the Selwyn and at Rockwood it occurs only in the form of a rich fawn-colored clay-iron ore, containing the remains of plants, and forming either nodules or continuous beds, which will someday be of value to the Colony.

I have before observed that the conglomerates consisting of boulders and pebbles of quartziferous porphyry are of local occurrence, but there is one exception in the outlier behind the Thirteen-Mile Bush range (Big Ben) to which I wish to allude. The base of the whole series in that distant locality consists of a loose conglomerate made up of boulders of Quartziferous Porphyry, quite similar to those occurring on the eastern side of the ranges; and as this outlier is situated amongst the mountains in a depression, the base of which is about 2,800 feet above the level of the sea, being surrounded by heights of 4,000 to 5,000 feet, it is difficult to understand whence the material for this conglomerate could have been derived, except from mountains of much greater altitude than at present exist, and having been brought by currents over the summit of the ranges west of the Thirteen-Mile Bush Range. A glance at the Map will at once convey my meaning, and show how difficult it is to account for their occurrence in such a land-locked locality, separated from the range consisting of Porphyries by a whole series of high mountains, unless we assume that the material for those beds was brought from another locality closer by, and now hidden from our sight by younger deposits.

I have before stated that along the eastern sides of the ranges no coal seams occur amongst these conglomerates, but there are some series of beds in two other localities which are doubtless of the same age, and which do contain coal seams. The first of them is situated in the Gorge of the Rakaia, filling a hollow amongst the Melaphyres. The general characteristics are here, the occurrence at the bottom of the series of large beds of shale with small seams of brown coal, changed into coal of an anthracitic character when in proximity to dykes and streams of dolerite, which at a later period have broken through or

flowed over them. These coal seams are covered by large beds of conglomerate, with which shales are also associated, but now of a more argillaceous nature, and containing only carbonaceous markings, or small pieces of driftwood changed into pitch coal. The other locality is at Rockwood, where the base of the series consists of fine tufaceous beds, made up of the material of the decomposed porphyry beds, and being succeeded by a series of shales, with beds of brown coal, gritty sandstone, and clay iron ore, which follow the steep contour of the ranges to such an extent that at first sight they have been mistaken for folded or greatly disturbed beds, caused by the eruption of volcanic rocks.

In both of these localities no fossils have been found, so that we have no data for fixing their age in comparison with the next beds to be considered. As I shall describe both places more in detail when speaking of the sections, these few remarks will, I think, be sufficient to point out their chief peculiarities.

If we assume that the beds containing brown coal, which long after their formation have been broken through by the dolerites, are of the same age, and constitute one series, and those with which these volcanic rocks are interstratified, constitute another series. The outlier in the valley of the Acheron might be considered to belong to the first series, although it contains fossils having the same facies as those next to be considered.

The other series consists of the Great Brown Coal Formation, which invariably overlies the conglomerates, and which again has two principal subdivisions, namely, altered and unaltered brown coals. The former occurr generally in isolated patches ; the latter is deposited all along the eastern portion of the Malvern Hills, forming more continuous beds, and sloping towards the plains. When examining the detached outliers of this brown coal formation, it becomes at once apparent that they are only a portion of once continuous beds, by which the lower ground was uniformly covered. By far the greatest portion of it being afterwards removed by denudation on a gigantic scale, only small portions in a few detached positions were preserved where favorable circumstances combined. This denudation was most effective in the Western portion during the post-pliocene glacier period, and only those beds escaped with which were associated dykes and streams of basaltic rocks, forming a protective cover over them. Similar favorable circumstances preserved the more continuous brown coal beds bordering

the Canterbury Plains in the Malvern Hills, as an examination of the Geological Map will show.

Before treating of these detached localities I shall first offer a short description of the continuous beds in the eastern portion of the district under review, in order to trace their similarity with those in the outliers. The porphyry conglomerates becoming less compact change into bluish sandy beds, which, in decomposing, assume an iron rust color; between them are imbedded layers of a limonitic sandstone often full of impressions of dicotyledonous leaves, which constitutes the separating bed of both formations, a fact to which I have previously alluded. Bluish sands and shales then generally alternate for more than 100 feet, after which the first series of beds of brown coal appears, consisting of two seams, of which the lowest is the largest, and which, in Surveyor's Gully, seems to attain the greatest thickness (over six feet). Shales and sands alternate above them for a considerable distance, the former containing two more sets of seams of brown coal, but of less thickness than the lower set. I shall give a full account of the characteristic features of these beds in the description of the sections. In the more northerly portion these brown coal beds are overlaid by quartzose white sands more than 100 feet thick, while near the Selwyn these siliceous beds are only inconsiderably developed, and contain grains of Glanconite. Upon them repose fossiliferous beds which are of great interest to us, because they contain not only numerous fossil Mollusks of the same species as those found in the Waipara, but also Saurian remains.

This lowest fossiliferous bed assumes, according to the localities where it has been deposited, various distinctive features, so that if two localities so close together as the Selwyn rapids and the Oyster Hill, a mile south of them, are compared together, we might almost believe that they belong to two different periods. Thus the fossiliferous beds in the Oyster Hill consist of a conglomerated mass of large black oysters with scarcely any other shells between them, whilst the beds in the Selwyn contain a great variety of Conchifers, Gasteropods, teeth and scales of fishes without any oyster between them, so shewing that the conditions under which the oyster beds were formed did not exist in that locality.

Again, half a mile to the north-east of the Selwyn, that is to say on the opposite side, the oyster beds make their appearance once more to the exclusion of all other shells. This occurrence might suggest to us that the conditions of the sea bottom in the centre of the present

valley and on both sides were quite different; for instance that a river discharged itself into the sea a little higher up the present valley, the sands and ooze here deposited preventing the formation of oyster beds, which can only flourish in comparatively still water, whilst on both sides and a little more inshore these conditions existed. Many other Mollusks which like a sandy or oozy bottom, might however, have selected the central locality as most congenial to their existence. More to the south, on the southern flanks of Mount Pleasant, the fossiliferous beds are of intermediate character, the big ostrea of the Oyster Hill and of the Oyster Gully being here mixed with a great variety of shells from the Selwyn rapids,—the whole being similar in every respect to the Waipara, and lying exactly in the same position as the fossiliferous beds in that distant locality. A peculiar Gasteropod, the Conchotyhra parasitica of M'Coy, occurs however in all the beds without exception, resembling also, in this respect, those of the Waipara.

My search for Ammonites, Belemnites, and other characteristic cretaceous exuviæ, was also in this district in vain, and I cannot conceive why the lower portion of the strata resembling so closely those of the Amuri Bluff in sequence and in lithological character, and having, doubtless, been deposited under similar conditions should not like these more northern beds also contain Belemnites, and some other characteristic fossils with cretaceous facies, if they had existed in the sea at that period. Saurian remains exist amongst them as in the Waipara beds, but they are neither numerous nor perfect, consisting mostly of rolled fragments.

Upon these calcareous beds repose in some localities, as for instance at the Selwyn rapids, green sands several hundred feet thick, divided by layers of calcareous and micaceous sandstone, each of a few feet in thickness, and full of fossils, mostly Conchiferous Mollusks. Some of these green sands are replete with casts of Fucoids and shells, too imperfect however for recognition.

In the lower valley of the Selwyn and its northern banks a bed of Basalt ends this series—having flowed over it while on the southern side of the river, a great thickness of still younger white quartzose sands rises above the valley in Harper's Hills. They are capped by streams of dolerite resembling closely the typical Anamesites of Germany by which the whole formation is brought to a close.

We have thus the whole series of the Waipara represented, with the exception that the green sands and quartzose sands do not enclose concretious of lime (septaria) with Saurian remains, and that instead

of the calcareous sandstone (the Weka Pass stone) the series is capped with the Anamesitic or Dolerite rocks. However, we have a similar series in the southern portion of this Province, in the neighborhood of Timaru, where the Weka Pass limestone also occurs, but subdivided by several Coulées of the Anamesites, identical with that of the Malvern Hills; and it would therefore not be too bold to assume that, from causes easily conceivable, such as submarine currents and the effect of fresh water, no limestone could be formed at the sea bottom which now constitutes the Malvern Hills, only Quartzose sands being deposited during the epoch when the great outflow of the Anamesite took place contemporaneously in both localities.

In speaking of these Anamesites it might perhaps be useful if I allude here to the various characteristics and age of the different basic rocks, which during that whole period have made their appearance, and through which some important changes have taken place in the district. There are *three* important divisions in the basic or basaltic rocks which appeared during this geological period in this part of New Zealand.

First.—Rocks coeval with or even prior to the formation of the principal Brown coal Beds, and by which, in the first case, the latter have been altered effectually, both vertically and horizontally.

Second.—Rocks appearing only after the deposition of the calcareous fossiliferous beds overlying the brown coal series, or even after the formation of the green sands.

Third.—Rocks of which the streams of Anamesite consist, forming a well defined horizon, and closing an important geological epoch in the district. The rocks of the first division are very peculiar. They have a dark greenish colour, are granular, and resemble in hand specimens some eruptive (diabasic) rocks of older origin. Some of them have the peculiar greenish tint which an admixture of Chlorite usually gives, although I do not think it exists in them.

In Germany, rocks of this character are named Hyperites, but I have no doubt that the analysis of the New Zealand Rocks will show that this resemblance is only apparent. No doubt the peculiar conditions under which these rocks made their appearance may account for their structure. They were, doubtless, deposited in shallow water, or even some of the beds might be of subaerial origin.

Two forms of texture are easily identified both occurring in the dykes and the coulées or streams. One of them more compact, although still having a doleritic and sometimes a porphyritic texture,

with small grains or imperfect crystals of Felspar amongst them. Another more granular and Amygdaloidal, the pores and cavities either lined with sphœrosiderite or filled with chalcedonic quartz. Some of the streams are of considerable dimensions, Mr. M. B. Hart having passed through one which has a thickness of about 75 feet.

There are two localities where dykes belonging to another series occur, having been erupted during the formation of the green sands above the Saurian beds, and have quite a basaltic texture. Their being of deep-seated submarine origin may account for this difference. In any case we have to classify them with the next series—the true doleritic rocks of which many have a porphyritic or even granitoid texture. They have been erupted after the formation of the Coal-bearing beds, often dislocating and altering them in a most remarkable manner and having preserved portions of these former more extensive strata from entire destruction.

In one locality at the Kowai corner they are unconnected with any of the younger sedimentary series, having broken through the palæozoic beds, which at the contact have suffered vitrifaction. They here form a small hill with a crateriform appearance, with a lava stream running in a southerly direction. The rocks on the summit of this little system are granitoid, whilst some dykelike projections which pass through them have a fine grained texture. Also here the rule holds good that that position which has cooled more slowly in the form of dykes is more compact and fine-grained than the streams which have a more porphyritic structure; besides the example just given, the Dolerites in the Acheron show very conspicuously this difference. The Felspar in some of these latter beds is most probably Nepheline. When speaking of the different sections annexed to this Report, I shall have ample opportunity of entering more fully into a description of these interesting rocks. The next series to be considered is the youngest. It occurs all along the eastern side of the district, forming large sheets of doleritic rocks, which have flowed over the bottom of the sea and afterwards when being raised to form subaerial hills, protecting the beds of loose Quartzose sands below them. There are several streams, mostly close together, which in the Harper's hills and the Dean's range show all their characteristic features. The first stream flowing over the sands has generally had a vitrifying influence; the sands have been melted for a few inches, or even one foot, being changed into a flint-like rock. In other localities Doleritic Tufas overlying the sands have protected them effectually, no change being visible.

Between the lava streams, which have a thickness varying from a few feet to nearly 100 sometimes, layers of Pitchopal occur often enclosing stems and leaves of plants; at some other localities Palagonite Tufas have been formed. These basic rocks have the peculiar character to which the name of Anamesites has been given by Leonhard, some of them are scoriaceous, the vesicular cavities lined with sphærosiderite; the latter variety would offer good material for mill stones, a similar rock being extensively used on the continent of Europe for that purpose.

Having given the general characteristics of these rocks, I shall now proceed to trace the zones of their occurrence. It will be observed that taking the two older series together, they form as it were a network round the Thirteen Mile Bush range, appearing in a few spots above the surface; thus beginning at the Gorge of the Rakaia we find Dolerites in two distinct localities more than a mile distant from each other—the lower portion having broken through and altered the brown coal beds in the centre of this picturesque gorge.

We again find them in the Gorge of the Acheron, having also here been erupted from two or more distinct centres and assuming different structure according to their position. The brown coals and shales in contact with the dyke like beds have undergone most remarkable changes—the first having been altered to a fine anthracitic coal, the latter to porcelain jasper like rocks—both exhibiting a false stratification parallel to the walls of the Dolerite Dykes. The coal bearing beds are overlaid in the Acheron by sandy or argillaceous strata in which fossils are imbedded, but mostly so much decomposed that except a large oyster only a few species could be determined. Some layers of limestone, consisting almost entirely of a mass of oysters divide the argillaceous sands into smaller beds. A third locality is behind Big Ben, the highest summit of the Thirteen Mile Bush range; here the volcanic rocks have made their appearance after the *principal* coal seam was deposited, but not before the succeeding smaller ones had all been formed, some of the dykes having a basaltic texture.

The various beds in this remarkable outlier, although situated nearly 2000 feet above the Selwyn beds, shew the same sequence as elsewhere; they have been deposited in a basin like form, but have also throughout an easterly dip.

Upon the coal bearing strata in this locality, green sands with harder fossiliferous and calcareous layers between them follow, and above them again quartzose sands. We thus see that the same con-

ditions for the deposition of strata of such various character occurred during a considerable lapse of time—according to the changes the sea bottom underwent, in being raised or depressed, the whole taking place during the same geological period.

In descending the valley in which the Big Ben beds lie, at its beginning in the ranges, we find nearly in the same line the Kowai beds, but they are almost entirely covered with post-pliocene alluvium, and even the drives passing through them gave only a partial insight into their characteristic features.

There are some conglomerates near them with small seams of impure lignite, the relations of which with the strata containing the altered coal seams are not at all clear. I shall describe them more fully in giving the details of the sections of this locality.

A continuation either of the Acheron or Big Ben volcanic rocks may be traced to the Broken river where dykes of basin rocks form a conspicuous land mark, and thence across the Waimakariri to the valley of the Esk, where similar rocks to those in the Kowai drives are exposed in high cliffs.

I have already alluded to the crater-like occurrence of dolerites at the Kowai corners, and may state that similar rocks are found on the other side of the Waimakariri, near Oxford, in View Hill and some other localities. Other important beds belonging to the second series occur near the Upper Selwyn at the southern slopes of the Thirteen Mile Bush range.

They form an outlier similiar to that on the opposite side of that high range. In their *western* portion, where the dolerites assume more the character of dykes, they are finely grained, whilst on the eastern side, where they have overflowed considerably the sedimentary beds through which they have broken, they appear in the shape of a rounded hill, and have a distinct and more granitoid texture, resembling closely the dolerites of Kowai corner. Another resemblance between the two outliers on the opposite side of that range, besides their longer axis stretching from W.S.W. to E.N.E., is the occurrence of the oldest or brown coal beds being confined to the north-eastern portion. In the Big Ben outlier the contact between the brown coal beds formed before the eruption of the dolerites could not be ascertained, but the largest seam of brown coal (a fine pitch coal) near the base of the series, contains coal of excellent quality and it is evident that the eruption of the igneous rocks has to some degree effected this improvement. In the Selwyn outlier the portion of the brown coal beds having been

deposited in the immediate neighbourhood of, or having been broken through by the dolerites in their close proximity, have altered to an authracitic coal, but as we leave them, the coal exhibits less and less the effect of their influence, and about 200 yards from the dykes it appears as quite unaltered brown coal.

The most important locality in that district is the outlier between Mount Misery and the Fourpoint Range ; all the beds also there are not deposited with a synclinar arrangement, but dip invariably towards the south-east. We have first the porphyric conglomerate beds consisting of shales, clays, quartzose sands and conglomerates most largely developed in the western corner ; upon these repose shales with brown coal altered to bituminous, glance or even authracitic coal by streams of a peculiar greenish dolerite, which is associated with them, besides these Coulées of dolerite we have rocks of a more compact basaltic structure, which have broken through the lower shales and coals in the form of dykes, being without doubt the channels by which the Coulées have ascended to the surface. Some of these igneous rocks are compact, others porous, the small cavities either filled with opaline Quartz or lined with Sphærosiderite. When the shales in immediate contact with these are visible, as for instance on a little hillock in the neighbourhood of Mr. Hill's drive, great changes in their texture and color become manifest. They are either burnt to red brick-like masses, (Laterite) or have assumed the texture and color of porcelain Jasper, and similar altered rocks formed under similar circumstances in many parts of the world. These shales, coals, and dolerites are the uppermost beds exposed in the western portion where Mr. H. P. Hill has undertaken his trial works. On the eastern, or Mr. M. B. Hart's side, the coal seams repose upon a dolerite stream of great thickness, but I have not been able to ascertain if they are also covered by similar igneous rocks, the hill sides being thickly covered with post-pliocene alluvium.

The first bed above the coal which is exposed to view is an Argillaceous limestone, enclosing large septaria, like portions of a more calcareous character, and which contain fossil shells. It is overlaid by quartzose sands, which again are capped by a bed of fossiliferous sandstone, consisting almost exclusively of the curious Conchothyra parasitica, over which white and yellowish sands have been deposited, abutting against the older formation of Cairn Range.

These younger beds have throughout nearly the same strike and dip, thus the sequence of the beds is not only the same as in the more

eastern portion of the Malvern Hills, but the occurrence of fossils of the same species proves that they have been deposited during the same geological epoch, and under the same conditions.

Another interesting outlier occurs on the North Western corner of Mount Misery when six to seven hundred feet above the valley, and also dipping to the E.S.E., first beds of porphyry conglomerate, and above them shales and unaltered brown coal are in existence, which appear to dip below the porphyries, but are only a small remnant of a large deposit now nearly entirely removed, and which is also abutting against those older rocks.

I have only referred to these important beds from a general point of view, because in describing the sections I should have to repeat myself had I given any details at present, and I must refer the reader to that portion of my report where I shall treat more fully on the subject.

I have already alluded to the fact that the upper beds of the series under review, the so-called Weka Pass limestones, do not occur in the Malvern Hills, their place being taken by loose quartzose sands, and the capping of Anamesitic rocks by which the series is here closed. The interesting series of tertiary rocks reposing upon the calcareous beds, and which plays such an important part in the Waipara, and more to the North, is entirely missing in the Malvern Hills proper, but five miles below the Gorge of the Rakaia calcareous or glaceconitic sandy beds occur on the left bank of that river cropping out below the post-pliocene alluvium. We have thus a proof that they are not altogether missing in the district, but that they have been deposited at such a depth below the present surface of the country that they do not rise above the enormous beds of post-pliocene alluvium, by which the whole country between the Malvern Hills and the sea shore is covered, except under peculiarly favorable circumstances. The beds exposed in the high terrace banks of the Rakaia are in some layers so replete with organic remains that the locality by the first settlers was already called the "Curiosity Shop," and, in fact, the quantity of fossils which can be collected is enormous, as some of the beds consist almost entirely of the exuviæ of animal life. Whilst many of the fossils are rolled, there are also others which seem to have been deposited in situ. The following list, giving a few of the principal genera, will best convey an idea of the richness of these beds in organic life:—

Micraster; Hemipatagus; Brissus; Rhynchonella; Balanus; Stems of *Pentacrinites; Cidaris,* two species; *Cidaris* spines; *Scalaria lyrata; Scalaria,* species; *Trochus; Cucullæa; Anomia; Natica; Lima; Pecten*

Hochstetteri; Pecten Williamsoni; Mesodesma; Waldheimia, two species; *Terebratula; Serpula,* various species; *Teredo; Lithodomus; Lamna* (teeth); *Carcharias* (teeth); Corals, &c., &c.

It is thus evident that these strata represent the beds, No. 12, of the Waipara, overlying unconformably the calcareous strata, No. 11, and the beds, No. 12, of the Amuri series also occupying the same position in regard to the Amuri limestone series. However, I wish to point out that the "Curiosity Shop" beds also contain some fossils apparently belonging to the same species as those occurring in the Weka Pass beds, No. 11. If this should prove to be correct it would shew that although there is unconformity between them denoting a great lapse of time, and important physical changes, nevertheless several of the species continued to flourish in the next period. It appears that these Rakaia beds have not been deposited on the shore or under the influence of tidal agencies, but that they have been deposited in deep water, and were brought together by submarine currents. The origin of such beds would have been difficult to account for had not the magnificent deep sea researches of Messrs Carpenter and Jeffreys, to which I have previously alluded, thrown great light upon this and other geological phenomena.

The formation of the remarkable assemblage of animal life found by these eminent savants in the Atlantic, at a depth of 994 fathoms off the coast of Portugal, affords us at once an explanation, or at least assists us to understand why and how similar beds in all geological periods could have been deposited. For the Geologist, as well as for the Zoologist, these researches are of the utmost importance, and I only hope that the Governments of New Zealand and of the Australian Colonies will, with their usual liberality, in their turn assist science by using some of their vessels for deep sea dredging purposes, which could be done without much further outlay in connection with obtaining the necessary data for the laying of submarine telegraph cables.

The next beds under review are of a far more recent orlgin, as they bring us to the ice period of New Zealand, when the glaciers occupying at present only the head of the Alpine Main Valleys reached the Canterbury plains, and covered with a network of gigantic ice streams, the whole country over which only the high ice-clad mountains rose in desolate grandeur and majesty. As I have in various publications fully treated of this subject, I need not repeat what I then stated of the causes by which the glacier period of New Zealand was brought about, or speak of the limits of the glaciers in that interesting era,

except where they enter into the formation of the Malvern Hills. I wish, however, to refer to two of my reports, printed by authority of the Provincial Government of Canterbury, namely, "Report on the formation of the Canterbury Plains in 1864," and "Report on the Head waters of the River Rakaia in 1867," in both of which I have collected a great deal of information having reference to both the Rakaia and Waimakariri Valleys. It will, therefore, be only necessary to speak here of the limits of the glaciers in the district under review, and to trace their influence upon its orographical configuration. The farthest point down the plains on which morainic accumulations are visible is in the so-called Woolshed Hill, seven to eight feet below the Rakaia Gorge. This hill rises about 100 feet above the plains, it has a triangular shape, and consists of shingle and sand, from which in many places angular blocks of sandstone, felstone and slates appear above the surface. These blocks have mostly been derived from the central chain, where they occur in great abundance. If we consider that the gigantic torrential rivers which issued from the post-pliocene glaciers had the power of destroying easily beds of such incoherent nature as morainic accumulations, which were barring their passage, it is evident that only in very favorable cases such morainic accumulations could have been preserved. It is thus evident that the lowest points to which the post-pliocene Glaciers reached are not always traceable, but the occurrence of such beds so far advanced as the Woolshed Hill to the principal morainic accumulations shows us that we can scarcely fix the limits to which the huge ice-streams of the New Zealand Glacier period reached. These Woolshed Hill beds having, doubtless, been formed by the Great Rakaia Glacier, it is evident that the latter must have had truly enormous dimensions at some time. We can conclude from the characteristic features of the Valley of the Rakaia, that during the extension of the glacier the Valley was filled from side to side, and that it was hollowed or scooped out in a very striking manner, principally above those localities where beds of peculiar hardness crossed it. The occurrence of these very hard rocks is the principal cause of the formation of Lake Coleridge, of which, however, I have treated fully in my Report on the Head Waters of the Rakaia. Where these beds occur we find that their remaining portions stand out in very bold characteristic forms, as Roches Moutonnées, which have given rise to such names as Gibraltar, Sebastopol, &c.

I have already formerly mentioned that the large opening of the

Rakaia existed before the glacier period, and I may here add that principally near the slopes of the high ranges on both sides this glacier action becomes very manifest. Dr. Hector as far back as 1862, pointed out to me that the slopes of the high ranges to the altitude of the post-pliocene glacier were invariably much steeper than the upper portion which had not been under this influence, and sent me a sketch of one of the Otago lakes where the ranges on both sides in a remarkable degree exhibit this peculiar feature. In comparing the upper and lower slopes of these Otago ranges with those of the Western slopes of the Thirteen Mile Bush Range the similarity of the angles is very striking, and suggests that the same causes must have brought about these characteristic outlines in both.

Some of the most peculiar looking Roches Moutonnées in the district are situated near these slopes, and an examination of them proved that beds of very hard semi-crystalline sandstone went here across the valley through which the ice plough cut a channel close to the ranges, as well as in different localities in the valley, but without being able to remove the rocks altogether; consequently portions of the rocks remained standing which were situated where the glacier stream had either the least power, or where two glacier branches having come from adjoining valleys had united and continued to flow side by side.

The sketch section No. 29, from the western slopes of the Thirteen Mile Bush Range through the remarkable Roches Moutonnées, called Sebastopol, to the Rakaia upper plains near Snowdon, will best convey an insight into the peculiar outlines of mountains which have been subjected to the great and long continued action of the post-pliocene glaciers.

The main glacier of that great New Zealand ice period coming down by the valley of the Rakaia, of which we can trace the limits with certainty, reached into the plains a few miles below Rockwood, and crossing them in a semicircular form abutted against the south-eastern slopes of Mount Hutt. It is also evident that the hard Melaphyres, Porphyries, and Porphyry conglomerates stretching across the valley where at present the gorge of the Rakaia is situated, formed a great barrier to the advance of the glacier, until the rocks were sufficiently ground down or removed to allow the glacier to advance beyond. There is also evidence when the post-pliocene glacier retreated that for a long time a large lake was formed above the Gorge, which in course of time was filled up with glacier mud (silt), and at the same time by shingle

deposits brought down by the glaciers and rivers, and which cover invariably the beds of silt. The formation of the gorge is of still younger origin.

Morainic shelves occur also at an altitude of 500 to 600 feet on the northern, and 200 to 300 feet on the southern slopes of the Snowy Peak range, thus shewing the height of the glacier above the valley and its general slope. During my examination of the district I have collected a great many new and interesting details on the effects of the glaciation of New Zealand, which, in order not to swell this report too much, I intend publishing on a future occasion.

The great Rakaia glacier, besides its principal outlet by the main valley, had another branch which descended to the plains by the valley of the Selwyn, having probably at an early period of its existence very large dimensions before the barrier across the main valley, formed by the porphyritic rocks, had been scooped out sufficiently by the great ice stream.

Only in very few localities, mostly 600 to 700 feet above the present valley of the Selwyn, perched blocks occur, which prove the existence of a glacier branch by this outlet, but as I shall shew when speaking of the post-pliocene alluvium, the glacier, when it had retreated so far back that it had its boundaries above Upton's Flat, throwing here a huge Moraine across the valley,—continued still to send a glacier torrent down by the Selwyn, the deposits of which capping still the greater portion of the newer sedimentary beds in the district.

Another large glacier descended by the valley of the Waimakariri, of which a few Morainic accumulations have accidentally been preserved. There is in the first instance the Razorback hill on the plains, near the junction of the Kowai with the Waimakariri, evidently the portion of an an ancient Moraine. Accumulations of the same character occur also on the western slopes of Abner's head; otherwise, with a few exceptional indications, the Waimakariri Morainic deposits have either disappeared below the post-pliocene alluvium or have been destroyed by the torrential rivers when the terminal face of the glaciers had retreated up the valley.

The designation "post-pliocene alluvium" has generally been adopted for the next beds under review, which have been deposited by the huge torrential rivers issuing from the great post-pliocene glaciers. These deposits form by far the greatest portion of the Canterbury plains, and are found in the Malvern hills to an altitude of 400 feet above the smaller river courses, and cover the greater portion of the

lower ranges giving them a somewhat plateau like appearance, through which afterwards the rivers, streams, and brooks have cut deep channels, at the same time rearranging them in various ways.

I stated before that an outlet of the great Rakaia glacier went by the main valley of the Selwyn, but we find on closer examination that instead of issuing by the present debouchure of that river into the plains, it turned in a northerly direction after having passed the western slopes of the Cairn range, and reaching the Canterbury plains north of the Dean's range.

I have also to draw attention to the peculiar silt beds which occur at the head of the Wai-ani-aniwha and of the Thousand Acre swamp; both were, without doubt, formed during the greatest extension of the post-pliocene glacier of which the Wai-ani-aniwha desposit was the result of a lake situated between the Waimakariri and Rakaia-Selwyn glaciers, whilst the two Rakaia branch glaciers enclosed a space now forming the low ground called the Thousand Acre swamp, both of which in their turn were partly filled up by silt over portions of which the rivers afterwards flowed forming large alluvial deposits. These silt beds therefore and the alluvial deposits lying upon them and forming low and flat hills, are the oldest formation of that kind in the district.

When the glaciers retreated, the rivers issuing from them laid their channels lower, but although cutting into the older deposits they not only partly rearranged the older alluvial beds, but continued to deposit new ones, forming a series of terraces all the way. In my report on the formation of the Canterbury Plains I have entered into details on the *modus operandi* of the post-pliocene and recent rivers, and will therefore not discuss the subject here, except to point out that the Waimakariri, when forming its portion of the Canterbury Plains, removed also largely a part of the older alluvial beds, which had been deposited by the Eastern Rakaia branch on the eastern side of the Malvern Hills. A similar denudation and rearrangement, but on a smaller scale, were effected by the Selwyn and Hororata, whilst the Rakaia, before it was confined in its present deep channel, acted in a similar manner.

A few localities being preserved by peculiar circumstances remained outside the line of shingle walls and fans in course of construction, forming lagoon-like lakes, which, in course of time, were mostly filled up either by white clay beds (Sohlthon of the Germans) or by peat, the result of vegetable growth, or they continue still to the present day

in the form of swamps and marshes, of which the eastern portion of the Thousand Acre swamp, and the lower parts of the Wai-ani-aniwha Valley, are the most important in that district.

It is thus clear that there are two different beds of somewhat similar character close to each other, but nevertheless owing their formation to two distinct causes, glacier silt being first deposited, and afterwards, when the glacier retreated, to the usual agencies by which lagoon-like depressions are filled up in course of time, mostly by organic matter.

III. Sections.

I have added to this Report a number of sections, in order to illustrate more fully the Geology of the District under review, selecting those lines which are of the greatest scientific and practical interest with which I became best acquainted either during the progress of the Survey of last year, or during my former labours in that district as Provincial Geologist of Canterbury.

Section I.—Beginning at the eastern end of the Malvern Hills, the first section starts from the southern foot of Mount Torlesse amongst the older sedimentary rocks, and where there is a remarkable folding of the series, exposed in the banks of the Rubicon. In crossing the flat formed of post-pliocene alluvium, and before reaching the bed of the river Kowai, a small hillock consisting of older sedimentary rocks is exposed to our view, without doubt only a small outlier round which the younger formation has been deposited, whilst more towards the east the carboniferous strata stretch, doubtless, without interruption to the centre of the valley.

In a report published in 1863 I have given an account of the quality, thickness, and peculiarities of the coal seams, and of the character of the rocks which accompany them.

Owing to the lithological structure of the basic rocks associated with them, the total absence of fossils, and the resemblance of the coal shales with some of the palæozoic shales in the immediate neighbourhood and on the opposite side of the valley, as well as the excellent quality of the coal which fairly can be compared with the best coals of New South Wales. I assigned provisionally a greater age to these Kowai beds than they really possess, but I added that, "We have here "only the outcropping end or edge of the coal basin before us, and it "would be unwise to begin to work the coal at such a spot, because "as is generally the case, the seams are not of that regularity which

"we may expect to find more towards the centre of the basin, and "although coal may be worked at almost every angle, it will be more "convenient to choose a spot where a lesser dip of the carboniferous "beds gives not only greater facility in working, but also offers more "advantage for raising the fuel. The best spot therefore to work "these coal measures will be more towards the centre of the basin, "and I would recommend borings to be undertaken at the southern "corner of Mr. Watts Russell's sheep yards, where I have no doubt "the dip of the seams will be inconsiderable."

However, instead of following my recommendations, the Kowai Coal Mining Company continued to drive into the hill sides near the original drive, neglecting the borings towards the centre of the valley, with the result that the capital was spent without obtaining the most important information required, viz.:—First: If the seams were continuing regularly towards the centre of the valley. Secondly: If their dip became gradually less. And lastly: If they were thickening in reaching the bottom of the valley.

It is, therefore, with great regret that I cannot give any new information on this important subject; consequently, a locality which filled the public as well as myself with great hopes for the future, has, through misdirected energy, been doomed to neglect for many years, and as far as I can see, there is little chance that the borings so much needed will be undertaken for the present. The scale of the general sections to which No. I belongs being too small for details, I have added another section, No. Ia, on a larger scale, giving the results of the examinations in the drive which was excavated under my directions in 1861. It will be seen from this section that as far as visible the principal coal seams were formed after the doleritic beds had been deposited, although to judge from the altered character of the coal seams overlying them, it is probable that other streams will be found to lie above them when the whole series has been properly examined more towards the centre of the valley.

Some of the small coal seams lying immediately below the dolerites are altered to an anthracitic, almost cinder-like mass, with Polyhedric partings vertical to the direction of the stream (Stengelkohle of the Germans), whilst the other seams vary considerably in character.

The director of the Geological Survey of New Zealand has published the analyses of several samples taken from this locality which will best give an idea of the great variety in their chemical constituents.

That the seams are irregular in thickness and quality was amongst

others proved by the fact that the main seams, 3 feet 2 inches thick, contained, 23 feet above the drive, excellent glance coal, while in the drive it was much deteriorated in character, being shaly and somewhat irregular. There is another important point not to be overlooked, viz., that one seam, 2 feet 4 inches in thickness at the base of the drive, runs out altogether before it reaches the roof, so as to suggest that it is only the beginning of a seam which, lower down, may swell to larger dimensions.

In excavating the drive I found that the coal had suffered greatly from saturation, so that it was almost impossible to get a fair section, especially of some of the smaller seams which, being sometimes shaly and impure, could only be examined with difficulty.

I have also added another section, No. Ib, in which I have shewn the actual outcrops and the relations of certain conglomerates to the coal-bearing strata.

As these conglomerates do not occur at the base of the latter in the drive it is impossible to say in what relation they stand to each other, the more so as they do not contain any pebbles of porphyry or other eruptive and plutonic rocks, consisting mostly of rolled fragments of sandstones, quartz, and chertose rocks. The cementing medium of this conglomerate is sharp white quartzose sand.

With these beds of conglomerate small layers of shale and impure lignite are interstratified. However, the whole might nevertheless represent the conglomerate beds at the base of the series, as there are some localities in which the drift wood enclosed in them has only been converted into a lignite, which shows still the woody structure.

The section of the palæozoic rocks between the Kowai and Hawkins, over Russell's Hills, was examined by me in the beginning of 1862, when I searched the whole ranges in the neighbourhood for indications of carboniferous rocks. The first rocks cropping out from under the Kowai coal measures at the hill side are sandstones, gritty or argillaceous, with smaller beds of slaty shales or clay slate alternating with them. They have mostly light colors, yellowish tints being predominant Two hundred feet above the valley of the Kowai a series of chocolate-colored slates appear, consisting of three distinct beds with dark sandstones and yellowish shales between them, and forming on the hill side strata of three, five, and ten feet in thickness; they are succeeded by bluish hard fine-grained sandstones.

Before the summit of the hill is reached the chocolate-colored slates crop out again, but now the last mentioned bed of ten feet in thickness

appears first, and the others follow in the same succession, so as to prove that we have not only a fold before us, but that the strata which compose it have been doubled back upon themselves.

Gritty and argillaceous sandstones, with light colored slaty clays, follow, continuing to the valley of the Hawkins, the whole demonstrating to what enormous flexures the sedimentary palæozoic rocks have been subjected. I have already alluded to the morainic accumulations lying at the Northern base of Abner Head, which consists in its Northern portion of finely grained sandstones and slaty shales. Before reaching the porphyry conglomerate, the older beds of the palæozoic series crop out at the Northern slopes, consisting of coarse gritty sandstones, sometimes tabular, and of conglomerate divided into smaller layers by shales and finely grained bluish sandstones.

The conglomerate consists here of pebbles and boulders of sandstone with a few rolled pieces of quartz amongst them. Descending the southern slopes of Abner Head we reach the porphyry conglomerate, or, more correctly stated, its representative, because the beds consist here of rolled fragments of coarse yellowish and whitish sandstones of the same lithological character as those of which the Cairn Range is composed.

Between them are small layers and nests of clay-iron ore, which mineral often forms the cementing medium. Occasionally fresh-water quartz, in lenticular shaped masses, occurs between them; there are, however, a few pebbles of quartziferous porphyry associated with the fragments of sandstone.

Having crossed the gully we ascend again, in following the section, upon the more plateau-like downs which stretch from here to the Canterbury Plains; we meet at first a large bed of ferruginous sandstone (limonitic) containing numerous dicotyledonous leaves, identical with those described by Unger. I may here observe that this sandstone has been used as building stone in the district.

Having passed this rock, the surface of the downs, with one single exception, is covered with alluvium, but descending to the Valley of the Hawkins the brown coal beds, hidden also here by the same alluvium, have been opened by several works.

I owe to Mr John Jebson some valuable information concerning the existence and working of different seams, which, together with my ormer and present examinations, has enabled me to draw the section No. Ic to scale in order to shew the relations of the different beds to each other. The whole series, from the first seams worked in 1861 to

the ferruginous sandstone forming its base, stretches 12½ chains along the banks of the river, dipping on the average at an angle of nineteen degrees to the south-east, and thus possessing a considerable thickness. In descending order there occurs first a set of two seams, consisting of

Brown coal	...	...	... 2 feet 8 inches
Shale	...	...	... 2 feet 6 inches
Brown coal	...	...	... 1 foot 2 inches

These two seams were worked in 1861.

Three and a half chains from this drive, now abandoned for some time, Mr Jebson first began to work, extracting coal from three seams of 11 inches, 14 inches, and 20 inches respectively. These seams were separated by small bands of fire-clay and micaceous shales. Afterwards Mr Jebson went lower down in the series, and six and three-quarter chains from the first workings, a new mine was opened, from which now brown coal of fair quality is extracted.

This set consists of two seams, each about two feet thick, dipping 18 to 19 degrees to the E.S.E., with two feet of fire-clay between them.

However, before the coal-seams are reached the drive passes through three chains of post-pliocene alluvium, which also occurs near the roof of the drive where the coal is extracted, so that there is no chance of obtaining the coal in following the seams upwards; a fact to which I alluded before in my practical suggestions. In ascending again the plateau and following it towards the Canterbury Plains, we reach near Mrs. Dean's Sheep Station a small hillock rising above the post-pliocene alluvium, an outlier of palæozoic sedimentary rocks, consisting of fine grained sandstone, and against which a bed of ferruginous conglomerate reposes unconformably. This conglomerate is identical with that on the southern flanks of Abner Head, and it would thus appear that a synclinal arrangement of these beds here occurs. The brown-coal measures having afterwards been deposited in the basin-like depression. To the south of this hillock the older or Rakaia post-pliocene alluvium still rises several hundred feet above the plains, and of which we meet another portion in Race-course hill, where, however, it has an anticlinal arrangement covering, without doubt, some older rocks, which rise here above the plains.

Section No. II.

This section, crossing not only the Thirteen-Mile Bush range, but also the whole Malvern Hills in their central part, will best convey a general insight into the whole structure of the district. It will also

show the extent of the altered and unaltered brown-coal beds in comparison with the older sedimentary rocks. Beginning at Lake Lyndon and crossing the Tower Ranges, between the Lake and the Thirteen-Mile Bush Range we soon reach in a depression an outlier north of the main chain, this outlier contains some seams of excellent brown-coal, of which one is 4 feet 7 inches in thickness, and is about two miles long and three-quarters of a mile broad where most extended.

As observed in a preceding Report, it doubtless owes its preservation to the existence of a large dyke and stream of dolerite, which have made their appearance after the principal seam was deposited, but before the uppermost ones were formed.

This dyke has a general direction from north-east to south-west, and has suffered great erosion from the main branches of McFarlane's stream, having cut through it, and in the gorges of which the globular, or polyhedron structure of this rock is well exposed. Where the dyke, or, as it appears, a ramification of dykes, crosses the sedimentary beds, the latter have been subjected to great alterations near the contact. None of them extend to the north-western side of the outlier, or even reach the creek in which the main seam is exposed, and along which I made a section at the end of 1861.

Owing to the great flood in 1868 a great deal more of the lower bed has been laid bare, a circumstance which has enabled me to complete my former section.

I pointed out previously that the lowest beds consist principally of porphyry conglomerate which seems to fill the bottom of the depression near its northern boundary.

Before offering the details of the section which is exposed in the main seam creek, I wish to point out that the coal seams in the northern portion of the outlier rise several hundred feet above that creek, and follow the contours of the older sedimentary rocks of Big Ben and its spurs, having at the same time caused several extensive slips. Strike and dip are here very irregular; I observed the following dips—S. E., 78; E.N.E., 52; N.E., 39—in close proximity, and in passing from one spur to another, whilst the main seam in the centre of the depression strikes S.W., 20.

The following beds were noticed by me in ascending order; the seams of brown-coal (or in some instances merely beds of Lignite) are accurately measured, whilst the thickness of the other strata is only approximately given. Palæozoic shales alternating with bluish

finely grained sandstones, form the hill sides at the junction of th Big Seam Creek; upon them repose shales and porphyry conglomerat about 60 to 80 feet:—

	Ft.	In.
Bluish sandy clays, changing into ferruginous sandstone	15	0
Brown-coal	0	11
Rust colored, ferruginous, and white quartzose sands, alternating with each other, enclosing driftwood changed into Brown-coal, sometimes still shewing the annual rings	11	0
Argillaceous slaty shale	3	0
Dark shale, changing sometimes into impure lignite	1	0
Yellowish clays changing into shales ...	0	6
Brown-coal	1	1
Sandy clays...	1	0
Main seam Brown-coal* (see Tables of Analysis, Dr. Hector's report, page 54)	4	7
This seam contains nodules of pale yellow clay (bolus) and other smaller ones consisting of Retinite.		
Dark shale	1	9
Shales and sands alternating	20	0
They are full of vegetable remains, changed into Brown-coal, but their form and structure shows that they were not derived from drift wood, but probably from marine plants (Fucoids), some of them appear as if they had been enclosed on the spot where they had been growing, once forming kelp-like masses.		
Brown-coal, more or less shaly... ...	1	9
Shales, carbonaceous with remains of plants	2	0
Lignite, shaly and inferior	1	4

* As the expression Brown-coal is now generally adopted by the English Geologists for the better qualities of lignite, I shall use the same in future to distinguish thus between the principal subdivisions.

Shale	0	9
Brown-coal	0	6
Shale	2	1
Brown-coal	0	8
Shale, somewhat slaty	2	0
Sands, ferruginous	3	6
Under-clay	1	9
Brown-coal	1	6
Shales, fissile	1	6
Shales, dark, more compact	5	0
Sands, ferruginous	2	0
Sands, argillaceous, pink, sometimes shaly	11	0
Brown-coal, containing a great quantity of sulphuret of iron	1	5
Shales, light grey	4	0
Shales, finely stratified	1	6
Clays and sands in different colors, alternating...	15	0
Sandy shaly clays	7	0
Brown-coal	0	7
Clays and shales, more or less sandy, with remains of plants changed into Brown-coal	4	0
Brown-coal	0	8
Shale	2	0
Sands of different colors	3	3
Beds of clays and sands alternating ...	4	0
Dark greyish clays	1	0
Greenish marine sands	1	9
Grey plastic clays	1	0
Lignite, inferior, and full of sulphuret of iron	0	6
Argillaceous shales, sometimes sandy ...	4	9
Ostrea beds (the oyster identical with that found in the Selwyn)	1	3
Very compact, but sometimes small quantities of green and pink loose sands between the shells.		
Sandy clays, grey, slightly stratified ...	3	0
Ostrea beds, like the preceding one ..	1	10

Green loose sands, glauconitic	0	6
Greyish slaty clays	4	6
Loose sands of different colors, ribboned	11	6
White, loose, quartzose sands	2	3
Variegated, loose, quartzose sands ...	9	0
Sands, partly rust-colored, partly pink or greenish, with an admixture of clay, sometimes forming a loose sandstone	8	0
Bluish clays...	0	6
Sandstone, in some parts hard and compact, in others less coherent, of a dark iron rust or greenish color—sometimes full of teeth of fish	0	10
Yellowish green sands, alternating with pink ones	3	5
Sands, pinkish, sometimes compact, and then more argillaceous, sometimes with a slight efflorescence of sulphur, or with remains of plants, changed to clay-iron ore	3	0
Greenish sands	1	0
Pinkish sands	1	6
Dark greenish sands	0	9
Pinkish sands	1	0
Yellowish greenish sands	3	0
Pinkish sands, sometimes variegated ...	1	0
Greenish loose sands, do. ...	3	0
Reddish brown ferruginous sands forming often a hard conglomerate mass, and including layers and nodules of clay or sandy iron ore	2 to 4 feet	

This last bed is not entirely visible, being partly covered with debris from the mountain side. It will be seen that in this section, along the banks of the creek, no doleritic rocks are exposed, but if we ascend the hill on the left side, and proceed about 300 yards in a south-westerly direction, a stream of dolerite makes its appearance, forming a crest which can be followed without interruption in a westerly direction for more than a mile across the different branches of the stream. First only of inconsiderable thickness, after a few hundred yards it already forms a wall about ten feet high, and about 400 yards

from this spot I obtained the following section. The lowest bed visible consists of shales, but being partly covered by debris I could not ascertain its thickness.

	Ft.	In.
On them repose gray sands	2	0
Ferruginous sands full of teeth of fish ...	0	3
White sands	6	0
Sandstone—Ferruginous and containing also teeth of fish...	3	0
Dolerite tufa	2	9
Dolerite (Dip S.S.E. 35)	10	0
Upon this stream repose conformably dark shales	15	0
Brown coal	0	8
Shales, ferruginous	7	6
Brown coal	0	7
Green sands (several hundred feet thick)		
White quartzose sands (several hundred feet thick), and abutting against the older sedimentary rocks of the Thirteen Mile Bush range, and shewing that also here the whole newer strata have no synclinar arrangement.		

I could not ascertain at what period during the deposition of the big seam creek beds the eruption of the dolerites had taken place, but think that it was towards the latter part, when the few uppermost coal seams had not yet been formed.

In another locality the ostrea beds have been broken through and altered near their contact with the dolerites, but there might have been at an earlier stage of the series a deposition of similar beds which do not appear in the Big Seam Creek.

More towards the west the whole depression is filled by whitish or greenish sands with the exclusion of the whole brown-coal series. The main seam consists of an excellent brown-coal (pitch-coal) which, doubtless, owes its superior quality to the altering agency of the dolerites. It is to be regretted that the locality where it occurs is so inaccessible, as it would otherwise find a ready market; but even this difficulty could perhaps be overcome if there were such an unlimited quantity of coal as to induce capitalists to invest considerable sums.

That part of the depression where the main seam occurs may be

said to be about three-quarters of a mile broad and one-third of a mile long, but owing to the fact that where the strata lie against the older rocks near the outcrop, the coal is more or less useless, being deteriorated in quality, irregular in thickness, with a great dip, I shall not be wrong in calculating that this main seam covers an area half a mile long and one quarter of a mile broad. This would give us, assuming the seam to be one yard in thickness to the very edge, about 300,000 tons. This estimate would not be too high if the ground in the centre of the depression, where the main seam has the greatest thickness, had not been disturbed, but as we find here great slips and considerable denudation, a further deduction has to be made from the quantity given above.

In ascending and crossing the Thirteen-Mile Bush Range, we pass over its highest peak Big Ben. On the northern flank of this fine mountain a dyke of dolerite occurs, which is, however, mostly hidden under the debris, and only in a nearly vertical cliff at the termination of a gully I could observe its approximate thickness and direction. It appeared to be about 10 feet thick standing vertical and running in a W.S.W. and E.N.E. direction.

Big Ben is composed of a variety of rocks which, often in close proximity to each other, vary much in strike and dip. There are some dark micaceous sandstones with fucoid markings near the summit and dark bluish slates dipping with so low an angle as 16 degrees, an occurrence of great rarity amongst these rocks, which generally have a much greater inclination. The broad summit consists of a mass of angular debris over which, here and there, reefs of a very hard blue sandstone appear covered with lichens, and from the interstices of which woolly Haastias and other Alpine plants of peculiar forms spring; whilst the chesnut-breasted Plover, the Ringed Dottrell, and the Alpine Wren give a little life to the otherwise desolate and silent aspect of the scenery. In descending towards the Black Hills we cross a deep valley near the sources of the southern Kowai and pass a variety of rocks of which some thick beds of black shale, sometimes friable or finely laminated, surrounding white kernels or strings of silicious limestone, and which have either been mistaken for coal, or during the gold fever for reefs, are very conspicuous. These Black-Hills, the drainage of which runs principally into the main branch of the Selwyn, are of no peculiar interest, consisting of the same succession of sedimentary rocks as previously described. In crossing the Selwyn and a small ridge of palæozoic rocks on its right banks, we reach

another outlier having, as an examination of the map will show, nearly the same features as the outlier behind Big Ben; the older portions of the beds consisting of seams of brown-coal with the shales accompanying them are in the north-east corner, while the south-western portion of the beds and of younger origin consist of loose arenaceous deposits.

There are two distinct ridges of Dolerite which run nearly parallel to each other, of which the northern one represents the line or fissure by which the eruption has taken place, whilst the southern ridge appears in the form of a stream which in its more western portion is interstratified with sandy strata, but in the eastern portion is of younger origin than the Brown-coal beds overlying them, and forming a long stretched hillock which abuts against the older sedimentary rocks of Flag-pole Hill. The outlier at the bore of that mountain is about a quarter of a mile broad, and the strata succeed each other in the following manner:—

The lowest deposit consists of 50 to 60 feet of argillaceous beds (Fire-clay) which are covered by shales of dark, mostly blackish, colors, and more than 100 feet thick. They are succeeded by light-colored micaceous shales like those from Hart's Mine, with several seams of Brown-coal between them, of which the largest is two feet nine inches thick. The shales gradually assume darker colors, and are about 120 feet thick. They are covered by shales of lighter tinge containing small seams of coal of which one is five inches in thickness. The latter has been altered to a considerable degree so as to have generally the character of a glance coal, whilst some portions nearer to the place of contact have already an anthracitic appearance.

The shales by which these small seams are overlaid become gradually harder, till close to the dolerite dyke they have the structure of porcelain jasper. The dyke itself, about twenty feet thick, has in some parts a porphyritic, in others a fine grained texture.

On the other side of this dyke the rocks continue to be in a highly altered condition, consisting of shales and clays for about two chains, when again the dolerites appear, now in the form of a stream filling the hollow between the former and the palæozoic rocks which form the bed rock of the whole depression. This dolerite stream has cooled with a granitoid structure resembling the rocks from the small crateriform system at Kowai Corner. Near the contact the shales have not only been altered considerably, but also possess now a false stratification parallel to the flow of the igneous rocks.

In the Copper-cliff Gully, near the western extremity of the outlier the dyke is about twenty-five feet thick, forcing its way through loose sands of a dark greenish color. Upon these sands repose greenish conglomerate, again covered by a considerable thickness of green sands which dip at a high angle (E.S.E. 54°), and over which the dolerite flowed in a stream-like form. From an examination of the junction of both beds it not only appears that the green sands were burnt red for several feet by the dolerites, but that after the cooling of the igneous rocks had taken place, an open space of about three inches wide was formed, which in course of time was filled up by a fine bolus-like clay with small streaks of black sand intermixed.

The section in the eastern portion of the outlier may be considered to be very instructive, proving that the igneous rocks, although able to effect some considerable changes in their neighbourhood, had not sufficient power to alter the seams of brown-coal which were lying several chains below them.

In crossing Flag Pole Hill, we pass twice through an anticlinal arrangement, which exposes to us the lowest beds visible in the district, viz: the conglomerates, and which here are overlaid by diabasic and chertose rocks. It will be seen from the section that there is a repetition of this combination of peculiar strata between the conglomerates, they occurring in two distinct horizons—separated by several hundred feet of unaltered sandstones, shales and slates. After leaving the outlier, previously described, and ascending the valley we first pass two beds of cherts of variegated colors, separated by a band of unaltered sandstone. Below the lowest of them a deposit of compact diabase appears, under which conglomerates and shales with an anticlinal arrangement are exposed. They are again overlaid by a series of diabasic and chertose beds, but now the latter overlie twice the diabases. Before we reach the next anticlinal, two more beds of the same character were observed.

I have already described in a preceding part of this Report the structure and the component parts of the conglomerates, and may here add that the shaly carbonaceous beds which lie at the base may be said to possess somewhat the nature of a culm. They are either black or dark iron-grey, friable or with a scaly texture, forming generally here seams of a few inches in thickness. This oldest portion of the series leads us to the summit of a saddle which separates the Four Point Range from Flag Pole Hill. On its western side and forming the crest of the first summit a large bed of marble occurs,

lying immediately above the conglomerate and in close contact to diabases and cherts. It possesses an average thickness of 30 feet, consisting of a fine grained white marble with greenish veins and streaks, and would form an excellent material for ornamental work were the blocks not so much jointed. It is, however, possible that in quarrying these beds the rock will become more solid. The same marbles occur in advancing towards the west on the northern slopes of the Four Point Range in a few more localities, but afterwards disappear.

Those near the pass previously alluded to, are the most accessible for working, and if easy means of communication with the plains are provided, one day will be extensively worked for the use of the lime burner. Before we reach the flat in which Mr. Hill's coal beds are situated, and after having crossed a great thickness of unaltered palæozoic beds, we pass two more series of cherts and diabases with small beds of limestone between them, some of which, however, seem too siliceous for practical use.

The next beds on Hill's flat are of great interest to us, from a scientific as well as from a practical point of view. In my progress report, dated May 2, 1871, and in the practical suggestions, July 5, 1871, I have already offered some details concerning the depression containing seams of altered coal, which is situated on both banks of the Selwyn bounded by Flag Pole Hill, Weather Hill, a portion of the Cairn Range, and Mount Misery. This outlier, which is about two miles long and half a mile broad, has been filled, first with porphyry conglomerate and the shales, sands, and fire-clays associated with them, and afterwards with ferruginous sandstones, shales, and seams of coal. During the deposition of the latter beds, the eruption of doleritic rocks has at different times taken place. The whole is overlaid by fossiliferous limestones, with white and ferruginous sands, the fossils contained in the former proving that these beds are of the same age as the unaltered brown-coal measures, which form the eastern portion of the Malvern Hills.

Mr. Hart as well as Mr. Hill has undertaken various trial works, by which I was enabled to gain an insight into the structure and sequence of a great portion of this formation.

From an examination of the Geological Map, it will be seen that only portions of the rocks by which the depression under review is filled up are visible, and that between Hill's works and Hart's mine, the upper portions of the beds have been either removed or covered

by post-pliocene alluvium—of the latter occurrence, Snob's hill forms a conspicuous example, but that this covering is generally only superficial is shewn by the cropping out of a layer of ferruginous sandstone belonging to the coal measures on the top of that hill, so that we are not wrong in assuming that the whole formation in that depression will be found not to have suffered so greatly from denudation as first appearances might suggest.

In order not to repeat myself I shall give here a description of the whole outlier, including Hart's side and works, which are situated on one of its extremities. Mr Hill, before he discovered indications of coal lower down the valley, had several shafts sunk and one drive excavated on the low downs above it in order to obtain the coal on his side opposite to Mr Hart's, but as the result proved he had begun too low down in the series. The rocks, which near the residence of that gentleman form the boundary of the valley, are chertose sandstone, through which a small dyke of quartziferous porphyry runs in a N.N.E. direction. On them repose porphyry conglomerate and loose gritty sandstone, through which a shaft twenty-six feet deep was sunk. A little higher up in the series Mr Hill had another trial shaft, which passed through sandy shales with carbonaceous markings twenty-five feet; both these shafts are situated on the sides of the downs. Also a small drive on the hill side was excavated, which passed through sandy shales, fire clays, and beds and nodules of clay-iron stone; and lastly a third shaft was sunk on the upper flat, of which Dr. Hector has given the details in his report, page 50, and which was carried to a depth of 51 feet, the last 15 feet passing through sands and fire-clays. The whole of these beds are covered by a thick bedded ferruginous sandstone, which forms the boundary between them and the next series containing the coal measures. It reposes partly unconformably upon the conglomerate. We have therefore the same sequence of beds as on the southern flanks of the Cairn Range and Mount Misery, although they are deposits formed in a small bay into which a channel between the two hills was leading from the cretaceo-tertiary ocean. The same beds are also existing on the eastern side of the valley above Hart's mine, where they have been exposed some years ago by a drive excavated for the extraction of fire-clays.

I have already alluded to the existence of the ferruginous sandstone which forms the boundary between both series, and upon which, in the first instance, sands and shales with carbonaceous streaks, and enclosing drift coal, have been deposited. As we ascend in the series

the shales become more micaceous or carbonaceous, and finally contain seams of coal. As yet the whole sequence of these beds has not been exposed, because Mr Hart's drive, shaft, and borings, make us merely acquainted with the lower portion of the beds, while in Mr Hill's new shaft and drive the upper portion is passed. I shall therefore treat separately of both, and give first the details of the upper beds.

On the low downs near Mr Hill's residence, about one and a half miles distant from the right bank of the Selwyn, several coal seams appear near the surface, as well as a dyke of dolerite, which forms also the eastern corner of Mount Golgotha. That this dyke was erupted after a portion of the shales was deposited is well exhibited in a low hillock where the shales have been altered, when in contact with this dyke, to porcelain jasper or similar rocks. Mr Hill, after having sunk several small shafts upon the different coal seams exposed by the plough, at my suggestion had a drive excavated in the sides of the low downs in order to convince ourselves of the sequence, thickness, and other characteristic features of the beds, and although it was to be expected that this would make us acquainted with the outcrops only, the result was so far encouraging that the same gentleman afterwards began to sink a shaft for regular mining operations.

The detail section No. IIa. of Mr. Hill's drive, drawn on a large scale, offers an insight into the position of the different beds; their relations to each other, and the causes by which the coal seams have been so remarkably altered.

The drive, which is 130 feet long, ends in a bed consisting of shales, which have always the same characteristics throughout the whole district, being either light-coloured micaceous, and then somewhat sandy, with carbonaceous markings, or getting gradually darker till they appear quite black, and do not then contain any mica.

It will be seen that the lowest lava stream reached by the drive forms only a pocket, having been deposited uncomformably upon the shales, and upon a partly destroyed seam of coal, which consists of a fine glance coal. At the contact with the dolerite, however, it has for several inches been changed into a peculiarly brittle anthracitic coal (Stängel-kohle of the Germans), with polyhedral partings, forming sometimes regular hexagonal little columns, and which stand at right angles to the flow of the igneous rocks. The two lowest seams cut by the drive are of great practical interest to us, as by following them in their downward course they are found to unite, and to form one seam, about four feet thick, and not far below the floor of the drive.

Having passed one other bed of shale, a small seam of highly altered coal is reached, upon which a dolerite stream, eighteen feet in thickness, reposes, and which is regularly interstratified with the sedimentary beds; it is vesicular at its upper and lower faces, and in the centre more compact, with large polyhedral partings. Upon this stream, which is the largest crossed by the drive, shales with small seams, or pockets of coal, again follow, after which another stream of vesicular dolerite descends from the roof, also interstratified with the shales, but thinning out and disappearing altogether before it reaches the floor of the drive. The same beds of shale continue being more or less hardened, and containing numerous carbonaceous markings and pieces of drift coal. Instead of lying in the same position, the next stream has evidently made its appearance after the shales had suffered considerably from denudation. This lava stream, after it had cooled, was without doubt subjected to a great extent to the powerful influence of the waves, as its upper surface has been rounded off, and a small seam of coal, following the outlines of the ground, has afterwards been deposited over it, indicating the extent of such denudation. Another series of seams, of which one is fifteen inches thick, follows, the whole having also been subjected to the action of a stream of the same volcanic rock, but visible near the roof of the drive only. Silt and alluvium cover the hill side.

We have ample proof that during the deposition of the shales and seams of coal, volcanic eruption repeatedly took place, by which the deposits were highly altered, and as on the other side of the valley, two miles distant from the locality described, the seams of coal are equally if not more altered, a stream of the same igneous rock having been discovered by me at the side of the hills and at the same time has been reached by a shaft, we can assume with a degree of certainty that this altering action of the doleritic rocks has taken place throughout the whole outlier. This similarity on both extremities of the deposits may further be adduced as a proof that the coal seams should also be found to stretch along the valley; additional confirmation of which is to be found in the indications of porphyry conglomerate, shales, and ferruginous sandstone on the low downs between both extreme points.

Having satisfied himself of the existence of the coal, principally by means of the drive referred to, Mr. Hill had a shaft sunk three chains from the appearance of the first fifteen inch coal seam in the drive, (not six chains as is stated erroneously in my Progress Report,

through a clerical error) when he passed through the following beds :—

	Feet.
Clay and Silt	40
Shales	20
Stream of Dolerite	13
Shales	11
Dolerites	3
Shales	6
Dolerite, globular	3
	96

Owing to a somewhat faulty construction of the shaft and the great amount of water which had to be raised, this gentleman found it more convenient to abandon this first shaft and to sink a new and larger one closer to the mouth of the drive, selecting a spot two chains distant.

When I paid lately a visit to that locality, the new shaft had already reached a depth of 50 feet, and had passed through the following beds :—

Clays and Silt	22 feet
Shales	25 „
Coal, altered	5 inches
Shales	Several feet

And I have no doubt that, if not too much troubled with water, the new shaft will soon reach workable seams of altered coal. Before proceeding, I may perhaps be allowed a few moments to an examination of localities in other portions of the globe where brown-coal beds have been deposited under similar circumstances, in order to convince ourselves that, although appearing so peculiar, the same conditions not only occur repeatedly elsewhere, but that, judging from analogy, we may reckon with some degree of certainty upon a successful issue of the mining ventures in that portion of the Malvern Hills.

Beds of brown-coal have been deposited in the district of Leitmeritz in Bohemia, over a large area, accompanied by eruptions of basaltic rocks, by which they have been altered for a considerable distance to anthracite, glance, and pitch coal. I may here observe that the unaltered brown-coal of that country is generally not of such good quality as that obtained from similar beds in the Malvern Hills. Some of these altered beds in Bohemia are not only of excellent quality, but have been worked extensively in many places with marked success, so

that for many years the coal has been extracted with profit to the owner. There are some mines which have been worked for nearly 200 years, and the coal taken from some of the altered seams is so much liked that it is known all over the country under the name of Salon-kohle (drawing room coal); the unaltered brown-coal of the same district is also extracted in great quantities from numerous mines.

That the extent of the beds, both of altered and unaltered brown coal, in the north-western portion of Bohemia is not only considerable, but also that they are extensively mined, may be concluded from the circumstance that, in 1866, 3221 concessions for coal mining were registered at the Berghauptmannschaft of Commotau (the chief official mining office of the district). Dr. C. F. Zinken, in his excellent work "Die Physiographie der Braunkohle" gives, Vol. I., pages 24 to 33, a list of analyses of some 150 specimens of brown coal mostly taken from German and Austrian mines of which many are very instructive and tally in a remarkable degree with those of coals of the Malvern Hills. Similar beds of altered brown coal, and which are also extensively worked, occur in some parts of Russia and Saxony.

In the newly annexed Province of Hesse Cassel mining upon altered brown coal has been flourishing since 1570 in the Habichts-wald, the coal having in many instances been deposited between the eruption of two volcanic streams, so that the basalts form the roof and floor of the coal seams. In other localities where the coal has been only partially subjected to the action of volcanic rocks, breaking either through as dykes or forming streams of small dimensions, it has not undergone such changes throughout, but only near the line of contact.

The Meissner is one of the principal points where both occurrences can easily be studied, as the seams in its neighborhood, (as for instance, at Hirschberg, near Gross-Almerode) have been mined for 200 years.

The seams are generally of great thickness, 20 to 30 feet, which, when overflowed by basaltic streams, have only partially been altered. The total thickness through which the effect of the volcanic heat has been observed, varies from seven to seventeen feet, according to the thickness of the lava streams.

Immediately below the basalts the coal is altered, for a thickness of from one to four feet, into anthracite. For the next three to eighteen feet it might be called a glance coal; then follow a quarter to three and a half feet of pitch coal, and below it three to four feet of black, hard, brown coal (the two latter qualities correspond with our unaltered brown coals), and finally the bottom of the seam is formed of from half to

four feet of unaltered lignite containing nests of earthy brown coal, but never any pitch coal.

The analyses of these coals are of great interest, of which Zinken, in his excellent work gives also the whole series, which, if compared with the table in Dr Hector's report, shows at once the great similarity. I could not refrain from giving these data because they prove that, although the conditions under which all these coal seams on the continent of Europe are worked are not so favorable as coal of the carboniferous period generally presents, nevertheless for several centuries they have been mined with profit to the owners and advantage to the country.

I may add that some of the fire-clays from Almerode, near the Meissner, are of such excellent quality that they are worked on a large scale, and even exported in considerable quantities to the United States of North America (see Zinken, Vol. I., Page 550.)

I have before observed that only in a few localities between Hart's and Hill's works indications of the coal bearing series have been found by me. I wish, however, to allude to one point in particular where rocks of this formation are met with, viz.:—Snob's Hill, an isolated hillock in the centre of the flats, which is almost entirely covered with older post-pliocene alluvium. A portion of the coal bearing series has doubtless been preserved below the last mentioned deposits, because in the centre of the hill a reef consisting of that peculiar ferruginous sandstone, which is associated with the coal measures, crops out. Crossing the River Selwyn from the northern point of that hillock we reach Hart's coal mine; and although I intended to describe it with the next general section, I think that it will be perhaps better to do so at present in order to have the whole informatien concerning this outlier together in the same part of this Report.

The opening between the palæozoic ranges, in which the coal measures have been deposited is here considerably narrowed, and about half a mile more towards the east the spurs of the hills on both sides close in still more, having all the appearance that they run here as a low saddle across the valley, and by which the coal measures are cut off.

In ascending the downs above the coal mines, we observe that they consist of post-pliocene alluvium, but in advancing about a quarter of a mile towards the east, where they begin to slope down towards the Wai-ani-aniwha, this formation disappears, and only silt of a whitish colour, sometimes with a rusty yellowish tint, is exposed in high banks

bordering the little creeks. Whilst the section No. III. shows only the general characteristics of the beds, in the detailed section No. IIb I have given all the surface features, showing the different strata which are visible, as well as all the localities where they are hidden by post-pliocene alluvium. Beginning with the lowest beds of this series the principal indications we possess of them were obtained some years ago in a drive which was made for the extraction of fire-clay, close to the spot where they repose upon the palæozoic rocks. The lowest beds, as far as opened up, consist here, first, of fire-clays, ten feet in thickness, they are overlaid by four feet of sandy clays, with pieces of drift coal (unaltered pitch coal), upon which eight feet of stratified ferruginous sands follow. For ten chains no rocks are visible, the hill side being covered entirely by post-pliocene alluvium, after which, about twenty feet above the valley, a portion of a stream of dolerite, partly decomposed, and having a globular structure, has been laid bare. Another four chains brings us to the exposed portion of the coal measures, which rises as a hillock about fifty feet high above the valley, being capped by post-pliocene alluvium.

The beds forming these coal measures consist in ascending order of—

	Ft.	In.
Whitish tabulated loose sandstones, about	10	0
Shales, light coloured	6	0
Altered coal	0	9
Sandy shales and clays alternating ...	2	5
Altered coal	1	1
Shales	1	4
Altered coal	0	5
Shales (dip at outcrop 31°)	7	0
Altered coal	0	5
Shales (dip at outcrop 25°)	18	0
Altered coal	1	8
This is the seam which is at present worked.		
Shales and clays	7	0
Altered coal	1	3
Shales and clays	5	6
Altered coal	1	2
Shales	5	3
Altered coal	1	0
Shales	5	7

	Ft.	In.
Altered coal	0	3
Clays and Shales (dip at outcrop 21°) ...	5	9
Altered Coal	0	8

This last mentioned seam may be of greater thickness having been partly removed. Above it the hill side is covered by alluvium.

Dr. Hector in his report has given an analysis of the coal mined in this locality, which in every respect agrees with the analysis of some of the best altered brown-coals of Bohemia (the so called Salon-kohle.)

It is only to be regretted that the seams are not thicker or closer to each other, and that the ground where we may expect the seam at present worked to be available, is so very much restricted that only a limited quantity of coal can be obtained from this portion of the coal field. From an approximate calculation made by me we may expect that in the locality under review 10,000 tons of coal can be obtained level, free from the seam worked at present, and about 40,000 tons by sinking—this, however, I consider as the maximum, having taken all favorable circumstances into consideration. This does not include any ground towards the Selwyn on the waste lands of the Crown. As the coal is so much altered we may expect that it has been greatly subjected to the action of volcanic rocks. The drive for the extraction of the coal has, however, been carried already for a considerable distance into the hill without the coal losing its good quality, which compels us to conclude that this action must have taken place over a considerable area. Between the coal measures as far as exposed, and the calcareous beds on the summit of the ridge no rocks are visible. I suspect, however, that one or two streams of dolerite may exist there, hidden from our view by the alluvium. At the same time there is some probability that some workable coal seams might exist near or between them, which could be reached at a small expense to the owner or owners of the ground in question.

Before proceeding further I wish to give here the details of the shaft, and of the subsequent borings, both conducted for Mr. M. B. Hart by Mr. H. Brodie, at the base of the coal measures of which I have just given the details.

I owe the particulars of those trial works to the last mentioned gentleman, which I have added to the Section No. IIB.

	Ft.	In.
Depth of shaft	80	0
Depth of bore hole at bottom of shaft ...	105	0
The first bed passed through is:—		
Black clay, intermixed with pieces of coal	12	0
This is without doubt a superficial deposit, having been formed from the destruction of the coal beds on the hill side, and after the partial or total removal of the loose white sandstone which reposes upon the dolerite stream.		
Dolerite	79	0
Having the same strike and dip as the strata above it.		
Black shale	22	0
Coal measures, shale and coal mixed ...	3	6
Blackish shale	17	0
Black shale	31	0
Sands of light colors, with small carbonaceous streaks	10	0
Sand and coal mixed	3	0
Sands with small carbonaceous streaks, also containing iron pyrites	5	0
Shale and coal mixed	4	0

When a depth of 185 feet was reached the water forced itself up so strongly through the bore hole that the work had to be discontinued. It thus seems that no workable seams exist below the huge stream of dolerite, which in lithological character resembles in every respect the igneous rock cut through in Mr. Hill's drive.

In examining some of the particles of sandstone brought up by the boring rod, I also observed that the coal contained therein was simply a black pitch coal with a brown streak, evidencing that the altering agency of the dolerite does not reach below the twenty-two feet of black shale lying immediately under that volcanic rock.

In ascending the Downs, south of the coal hillock, the first rocks reached in situ consist of a bed of argillaceous lime stone, containing large and more calcareous septaria, in which a few rolled fragments of saurian bones, with panopœa and fragments of a few other bivalves, are enclosed. The panopœa is of the same species as that

occuring in the beds at the Selwyn rapids, and occupying a similar position above the unaltered brown coal beds in that zone. This septaria lime stone will, I think, form good material for cement. This bed is overlaid by loose green sand, with which occasional layers of limonitic sandstone are interstratified; they gradually change to white sand, which, in their turn, are capped by a stratum of fossilliferous sandstone five to six feet thick, and consisting almost entirely of the Conchothyra Parasitica of McCoy. I also obtained from the same a large Pholadomya, as well as a small Mactra and a Cardita, the two last mentioned, however, in an imperfect condition.

As these strata occupy exactly the same position as beds of the same lithological character, and contain the same fossils, as in the front ranges of the Malvern Hills above the unaltered brown coal, there is no doubt in my mind that both, in common with the Waipara beds, belong all to the same geological horizon quite distinct from the Amuri series, with which, in many respects, they have a great resemblance.

This Concothyra bed is overlaid by white and yellowish quartzose sand, abutting against the sedimentary palæozoic rocks of the Cairn Range. In my preliminary reports I have given a calculation of the contents of the whole outlier, and have come to the conclusion that we may reckon upon at least 1,500,000 tons of altered coal as being contained therein.

Since then I have visited twice the locality in question to inspect the progress of the works, and although unfavorable circumstances, to which I have previously alluded, have prevented the opening up of the seams more towards the centre of the flat, and by which my views previously expressed would have been confirmed, I confidently hope that the coal will shortly be reached, and will afford ample material for active mining operations, both to the profit of the coal owner and to the advantage of the general public. I am well aware, where igneous rocks are present, that disturbances must be expected, often making all human calculations of no avail, but I wish to point to Bohemia and to Hesse Cassel, and the occurrence of the altered coal there, which under similar circumstances finds employment for thousands of miners.

At the same time, I must express my regret once more that the former Kowai Coal Mining Company did not make the so much wanted borings towards the centre of the Kowai Flat which I so strongly recommended. Streams of similar extension as those of Bohemia might also here have preserved large seams of altered coal

from destruction, and thus have offered a great field for profitable enterprise to the inhabitants of the Colony.

In ascending the northern flank of Mount Misery, we observe in several localities beds of porphyry, conglomerate, and tufa occurring there, generally following the outlines of the mountain. Nowhere, as previously observed, do we find any older sedimentary rocks exposed below the porphyries, which appear here to have been erupted in large masses. Generally, they have a granular texture and trachytic touch, and are partly decomposed, probably from having been exposed so long to atmospheric action. In that case, the garnets have disappeared, and only an iron-rust stain betrays where they once existed; occasionally, however, harder portions, in dyke-like masses, appear amongst them, which have a felsitic texture, and having offered a better resistance to the atmospherilies, a few lines from the surface the garnets are still intact. The western portion of Mount Misery, and some low hills on its southern flanks, exhibit this state of preservation very conspicuously. Reaching the southern flank of that mountain, 500 feet below the summit, the porphyry conglomerate is developed very extensively, principally in the south-eastern corner, where it consists of an almost endless succession of sands, shales, and conglomerates—the two first-named varieties have sometimes carbonaceous markings, or even enclose small pieces of drift coal, generally with a brown streak.

Between them and the fossiliferous beds, which by their hardness have offered effectual resistance to the erosive action of the streams, the beds of brown coal and of loose quartzose sands cover a considerable space. They have generally suffered greatly from denudation, or are covered with alluvium. Only at one spot in that region the outcrop of the brown coal seams near to Oyster Hill has been exposed by a farmer in digging a drain, but except proving their occurrence no other information could be gained, the space being too limited.

Surrounded partly by swampy ground, partly by the newer post-pliocene alluvium of the Selwyn, the next beds which claim our attention form the isolated so-called Oyster Hill. Its northern base, shewing also its lowest strata, consists of white quartzose sands which gradually change into a ferruginous loose sandstone about thirty feet thick. This is overlaid by another bed of white sand of great thickness, but separated in nearly two equal portions by a stratum of fossiliferous sandstone about five feet thick, consisting almost entirely of specimens of a large black oyster, which form such a conglomeration that it is almost impossible to obtain any entire shells from it.

Amongst them are also a few other species such as panopœa, venus, and conchothyra parasitica.

Above these white sands, a bed of limonite sandstone is deposited, sometimes of great hardness and several feet thick.

A remarkable feature of the beds in this hill is their great dip S.E. 58 °, and which may perhaps be accounted for by partial denudation of the lower beds before the white sands were deposited upon them.

The ostrea belongs to the same species as that found in the Waipara.

Leaving this hill, and crossing the lower portion of the 1000 acre swamp, we reach the northern foot of Harper's Hill, by which this swamp is bounded on one side for several miles. The lowest beds to be observed in that interesting little range are exposed below the junction of a creek, which issues from the swamp, with the Selwyn, and in the banks of that river. They consist of dark sandy clays, sometimes micaceous, gradually changing into sands which are finely stratified, and contain small concretions of darker glauconitic material, the whole dipping S. by E. 19 °.

In ascending the slopes of the range we find invariably where any rocks *in situ* are visible that they consist of quartzose sands of a whitish color, some of them snowy white, being an exact counterpart of the sands of the brown coal formation in Rhenish Prussia.

As the sands of the latter country are derived from the decomposition of quartzose trachytes, so the sands of our brown coal beds are portions of decomposed quartziferous porphyry.

These sands in Germany are of great value for the manufacturing of glass, and are extensively used for that purpose, and it is worthy of notice that some of these sands, when of great purity such as those of Bardenberg, Herzogenrath, and Nievelstein, are exported in great quantities to Great Britain for that industry. (Zinken, Braunkohle, Vol. I. page 600.) Also in Bohemia many manufactories of glass are supplied from the products of similar beds.

Above these sands, which for th e uppermost ten to fourteen inches have been changed into a hard flint-like rock, repose fifteen to twenty feet of volcanic tufas, consisting of ashes and lapilli, after which the stream of Anamesite appears about sixty feet in thickness in its greatest dimensions, and gradually, in descending, getting thinner, till near the Selwyn Bluff it has dwindled to twenty feet.

Between the Coulée and the next bed a peculiar agglomerate

twenty to thirty feet thick appears at the Bluff, which has sometimes the character of a palagonite tufa, whilst higher up, near the summit of the range, it narrows to as many inches, and consists of a yellowish or blackish pitch opal, which often contains leaves and stems of dicotyledonous plants. The upper bed is more porous than the lower, the cavities generally lined with Spherosiderite, and would form excellent material for mill stones. Some of the highest parts of Harper's Hill are formed of a third stream by the same volcanic rock, which is however of inconsiderable thickness, and is also separated from the middle stream by beds of tufas and tufaceous sands. It has often been removed on the southern slopes immediately below the summit, and lower down is covered by the older post-pliocene alluvium, of which I have previously given a description.

Two hundred feet below the highest summit at one locality, situated above an old Shepherd's hut, large blocks of ferruginous quartz rise above the alluvial surface beds, probably the deposits of thermal springs. The section along the right bank of the Selwyn, from the junction of the Swamp Creek to the Bluff, is very instructive, offering a clear insight into the formation of that portion of the beds under review.

Section No. III.

This section, which follows a line along the Northern bank of the Selwyn for a considerable distance makes us acquainted with some of the remarkable details of the geology of the Malvern Hills.

In the second part of this report I have already given the principal features of the Diabasic beds, and have pointed to their necessary connections with the marbles and chertose rocks as they occur in Frank's Knob and elsewhere.

It will be seen from this section that that series forms here a steep synclinal, but that at the same time the fine stratum of marble of the Western is not existing on the Eastern side of the fold, once more showing the limited occurrence of the calcareous rocks. Travelling a short distance from that hill to the so-called Copper Gorge in the Selwyn the marble has already disappeared, and we find only chertose beds in its place on both sides of the river. From here to the termination of Wether Range, a fourth of a mile above Hart's mine, there is a succession of sandstones, slates, and shales, indicating several more folds of the upper beds of this palæozoic series, and dipping generally at a very high angle.

Before we leave them and reach the newer sedimentary beds in the right bank of a small creek along which the road leads to Russell's flat, some beds of fine grained sandstone and of slaty shales contain fossils. They are apparently Bivalves, but too indistinct for identification.

I have already, in describing the preceding section, given the results of my examination of the depression in which Hart's coal mine is situated, and shall now proceed to offer a description of the geological features of the Cairn Range. As before observed, this isolated range affords us an excellent insight into the structure of the lower beds of the palæozoic series, as well as into their relations to each other.

I have already alluded to the remarkable fact that the beds of which they are formed have a far more recent appearance than those which are situated several thousand feet above them, and if we combine with this phenomenon their generally inconsiderable dip, it is not to be wondered that they might mislead as to their true position, the more so as their junction is generally concealed under post-pliocene alluvium or *debris* of more recent origin. Thus whilst the overlying rocks in the gorge of the Selwyn stand sometimes vertical, and generally at an angle of 60° to 80°, we meet in the Cairn Range beds which lie nearly horizontal, and when the conglomerates form the surface of the summit or of the sides of the range, they almost appear as if they consisted of post-pliocene alluvium, their binding medium being of so incoherent a nature.

The lowest beds visible consist of shales of an earthy or scaly culm-like texture; they are very much twisted and contain kernels of clay iron-stone between these irregular layers of culm, of which they are principally composed: these shales in these characteristics resemble those observed by me in a deep gully at the base of Flag Pole Hill. In the Cairn Range they are overlaid by a whitish coarse-grained tabulated sandstone with stains of iron rust; conglomerate then follows fifteen to twenty feet thick, separated by small beds of sandstone into several distinct layers. Marly clays four feet in thickness repose upon it with small divisions of sandstone.

We are enabled to observe that, during their formation these deposits were doubtless only occasionally covered by water, when this took place new material was added to them acccording to the conditions then existing, either as a layer of sand or of clay marl. That sometimes they were left high and dry, exposed to the effects of a powerful

sun, is well shewn by numerous cracks formed in the clay marls, which are several inches wide and deep. These fissures are filled with pebbles, whilst they in common with the clay marls are covered only by a fine grained sandstone. Thus it is evident that the water which carried the shingle across the flat was too rapid to leave any of them behind, except in those previously formed cracks. The section No. IIIA, is a copy from my field book.

These clay marls are covered by beds of flaggy sandstone about fifty feet thick, their separation into thin beds is generally effected by small layers of clay marls which continue to be still present. Some of the coarser sandstones have a calcareous matrix, others have their surface coated with a crust of calcareous spar.

Some of these rocks which would form a fine building stone, are full of impressions of fossil ferns, almost exclusively a species of Pecopteris, but occurring in various stages of growth, so that they might be mistaken for several species. I also collected a few specimens of Tæniopteris amongst them. I could not, however, find the Unio, to which Dr. Hector alludes in his report as occurring also in this locality.

New beds of conglomerate cover these sandstones, followed again by another large series of similar rocks with a few smaller beds of conglomerate between them, and which form the highest summit of the Cairn range. In some of these sandstones instead of the ferns, carbonaceous markings as if produced by seaweeds, in others as if by sedges, are not unfrequent.

The lower portion of these beds, after disappearing near the Selwyn Flat, with an E.N.E. dip, crop up again in the river, where the porphyry conglomerates repose unconformably upon them, but now dipping N.W. 64°.

The river Selwyn having below that point washed for nearly a quarter of a mile the younger alluvial deposits away, we are enabled to examine in detail the whole lower portion of the porphyry conglomerate series, which here makes its first appearance. The lowest stratum which reposes upon the highly decomposed surface of the palæozoic rocks, which have doubtless for a long period been exposed to atmospheric and afterwards to tidal influences, consists, first of dark clays, followed by shales, with small layers of conglomerate interstratified between them, and dipping 41° to the S.E. This conglomerate at the base of the series is mostly made up of small pebbles of older sedimentary rocks, with a few occasional pieces of quartziferous

porphyry very much decomposed amongst them. It passes into a coarse sandstone, with numerous carbonaceous markings. Two chains from the junction of the two formations, the newer beds have changed their strike, dipping now to S.S.W. 29°. The three varieties of these rocks, conglomerates, sandstones, and shales in great variety of texture and color alternate almost every few feet with each other. Two and a half chains from the junction the beds are full of pieces of drift wood changed into glance coal, and the first layer of clay iron ore appears either forming nodules lying in the plane of stratification or even forming continuous beds six to nine inches thick, containing impressions of plants, mostly imperfect dicotyledonous leaves. This constant alternation of the beds, as previously described, continuous to eleven chains from their beginning, containing at several spots great quantities of clay iron ore. The locality at this point is known as the Upper Precipice, and consists of beds of coarse flaggy sandstone and porphyry conglomerate, from which now pebbles of sedimentary rocks have disappeared. Between this upper and the lower or Great Precipice no rocks are visible along the hill side, the river making a bend forming a small flat between it and the former. At the apex of this bend, however, the same rocks are exposed in the bed of the river exactly of the same character and sequence as in the Upper Precipice, but having now an opposite dip (E.N.E. 32°) and showing that the whole series has here a synclinal arrangement.

Section No. IIIb. gives the details of the relations of these beds to each other, proving that there is unconformity between the upper and lower beds of the same formation, and that the lower portion had suffered denudation to some extent before the upper beds were deposited upon them.

Some large nests of coal of good quality, but derived from drift wood, lie at the lower precipice amongst the sandstones and conglomerates. The latter forms here a very thick stratum, which runs up to the summit of the range, and can be followed all the way to the Wai-ani-aniwha.

It is also remarkable whilst at the upper precipice the conglomerate contains principally pebbles of quartziferous porphyry, the lower precipice beds contain again, besides the latter, a great quantity of boulders of chert, sandstone, felstone, and slates, some of them having certainly been derived from the central portion of our Alpine Ranges.

Deposits of loose, coarse sandstone are associated with the latter, and now continue to alternate with each other for a long distance till

we arrive at the Church Gully, where the conglomerate dips E.S.E. 20°. A few chains lower down in the gully, where I obtained this bearing, no rocks are visible, after which the brown coal formation is reached, consisting as far as exposed, and in ascending order of

	Ft.	In.
Shales ... ... Thickness unknown.		
Brown coal	0	6
Coarse sandstones, with carbonaceous markings	10	2
Limonite sandstone	1	0
Coarse sands	8	1
Limonite sandstone	1	10
Micaceous shales, partly covered by alluvium, the whole dipping E.N.E. 19°.		

About 100 feet above the bottom bed of this section the Ostrea beds appear on the hill sides, which might lead us to conclude that the brown coal seams, which less than a mile distant both to the North and to the South are so well developed, are here either of inconsiderable thickness, or else that they lie above the Ostrea beds, which however in Oyster Gully and in Surveyor's Gully have a different position. However, the country is here so extensively covered with post-pliocene alluvium, that I consider this portion of my work to be rather unsatisfactory, as I could not obtain the necessary sections to clear up this point.

In descending into the Selwyn we observe above the so-called rapids, where the river passes through and over beds of fossiliferous limestone and hard calcareous green sands, that the brown coal formations here cross the river. There are apparently five seams, of which the lower ones seem to be the largest.

These indications are spread over a distance of from three to four chains. However, I could not ascertain what portion of them was coal, and what was shale, owing to the depth of the water. In 1861 I opened up two small seams in the Terrace, of which one was about two feet thick. They evidently belonged to the upper portion of the series, but the water rising rapidly in the excavation precluded my following up the investigation.

I think it would be worth while to the owner of the property in which these seams are situated to have a small trial drive excavated in the bank of the Terrace which would settle this question, as there is no reason why a seam of such thickness and quality as that in Surveyor's

Gully should not exist here, and which could also be worked level free. I wish also to give here some details of the brown coal beds north of this point, in and near Surveyor's Gully, as the seams of that locality will doubtless soon be worked to a considerable extent.

About 100 feet above the valley of the so-called Surveyor's Gully, in a small creek joining the main valley on its left bank seventeen chains above this junction two seams of brown coal (pitch coal) exist, of which the lowest is over six feet thick overlaid by a three feet seam, but separated by about two feet six inches of shales, both offering about nine feet of excellent brown coal for extraction. In my progress report, page 140, I have transcribed the chemical analyses, which shews that both seams contain brown coal of very good quality, and superior to the unaltered brown coal of Bohemia so extensively used for steam and household purposes in that part of Europe. Five chains below these seams, lower down the valley, the shales are again exposed, and contain two smaller seams, one and a half to two feet thick, dipping E.S.E. 19°. I traced also similar seams to both sides of the Surveyor's Gully, of which I had lately one exposed to a thickness of two feet six inches, but, owing to the great amount of debris above it, without being able to obtain a measurement of its entire thickness. In crossing the hill, which forms the left bank of Coal creek, we reach Oyster Gully, a branch of the Wai-ani-aniwha, where again the coal measures are exposed in a deep gorge at the head of that creek. They still contain excellent brown coal, but without a great deal of work it is impossible to ascertain what is the number and thickness of the seams. Both strike and dip of the coal measures in that locality are, however, identical with those of the seams of Coal creek about a mile distant.

Following the formation towards the main branch of the Wai-ani-aniwha, coal and shale occur repeatedly either on the hill side in landslips or in the beds of deep creeks, so as to convince me that over a large area the stratigraphical conditions are of great regularity. At one locality near the main creek, the shales are altered to porcelain jasper and burnt argillaceous shale, probably by the burning of a seam of coal near them. I believe that I have not been over-estimating the quantity of coal which could be extracted level free in Surveyor's Gully and its neighbourhood (3,200,000 tons), but it is evident that if we add the available coal on the southern side of the Selwyn and on the northern side of the Wai-ani-aniwha as far as the banks of the Hawkins, a far greater quantity will be at our disposal, and which might offer remunerative employment for many years to come to a

mining population, if facilities were offered to transport the coal to the plains at a reasonable figure.

In the Laboratory Report of the Geological Survey of New Zealand for 1871, a complete table of the composition, both proximate and ultimate, is given of a complete series of the coals of this district, to which I beg to refer. Examining the beds which near the Oyster Gully, midway between the Selwyn and Wai-ani-aniwha, repose upon the brown-coal beds, we find that they consist first of about ten feet of limonite sandstone overlaid by white or bluish loose quartzose sands of a thickness of nearly 100 feet. These incoherent deposits are covered by a bed of bluish calcareous sandstone with teeth of fish (*Otodus*). The same contain, more to the north, casts of Bivalves (*Panopœa* and *Lucina*). It is covered by a fossiliferous layer consisting almost entirely of oysters (the black large *Ostrea* of the Waipara, etc.). Amongst them a few casts of Conchifers and Gasteropods are also present, of which *Natica* and *Dosinia* were most easily recognised.

Upon the oyster bed, which closely resembles that of Oyster Hill, repose bluish sandy clays, several hundred feet in thickness, separated into several beds by a few layers of micaceous sandstone, the whole capped by a hard limonite sandstone which crowns the hill sides, having best resisted the disintegrating agencies here at work.

They are succeeded by very thick deposits of green sands which are overlaid by a stream of a somewhat compact dolerite, so that now properly it may be called a basalt. On the surface of this stream, which closes here the series, the older post-pliocene alluvium reposes, forming downs a few hundred feet in height and which slope towards the Canterbury plains.

Comparing this Oyster Gully section with that of the Selwyn, we find that the sands overlying the brown-coal measures in the last mentioned locality have dwindled to very small dimensions. They are succeeded by a bed of hard fossiliferous bluish limestone with veins of calcareous spar. This rock has resisted the erosive action of the water to such an extent that portions of it stand as cliffs on both sides of the river and in mid-channel. Ten to twelve feet thick, it contains a considerable quantity of fossils, which however are often rolled and very fragmentary. I obtained from this bed, which dips E.S.E. 28°, a good many exuviæ, such as portions of the scapula of a Saurian, teeth of *Lamna* and *Hybodus*, scales of the latter, *Dentalium*, *Inoceramus*, *Cardita*, *Venus*, *Struthiolaria* (?), *Conchothyra parasitica*, *Natica*

Dosinia, *Lucina*, *Mesodesma*, *Pholadomya*, etc. It is overlaid by a hard bed of calcareous green sands, full of fossils (*Arca*, *Lucina*, *Tellina*.)

As we ascend in the series these green sands become lighter in color, and change gradually into white quartzose sands, but still with grains of Glauconite mixed with them. They are intersected by hard beds of calcareous and micaceous sandstone of light colors, forming protuberances, but sometimes also replete with distinct blackish Glauconite grains.

These hard beds contain teeth and scales of fishes allied to *Otodus* and *Hybodus*, and casts of *Turitella*, *Lucina*, *Panopœa*, *Dentalium*, etc.

After a short distance, the quartzose sands of white color disappear, and green sands, of deep green tints, take their place, full of casts of fucoids, and having a greater dip than the beds below them, so that near a stream of igneous rock, which closes the series, they dip east 48°. This stream of basalt is about fifteen feet thick, and has a polyhedral structure. It forms the last visible bed of the cretaceo-tertiary series on the left bank of the Selwyn; from here for several miles the cliffs bounding that river on that side consisting only of alluvial deposits.

There is another section of the same series attached to this Report which deserves a passing notice (No. IIIE.), situated on the northern side of the Wai-ani-aniwha.

The porphyry conglomerate is narrowed on this line to a bed of inconsiderable thickness, possessing, apparently, a greater dip than the coal-bearing strata above them. The matrix is very ferruginous, so that the whole has a limonitic appearance.

The shales of the carboniferous series exposed on a small hillock are burnt, and even some pieces amongst them appear as if they were derived from brown coal which had suffered slow combustion. On the other side of the hillock white quartzose sands are exposed, which, however, disappear below post-pliocene alluvium, forming for several miles the downs which stretch from here to the northern slopes of the Dean's range, and in an easterly direction to the banks of the Hawkins. Deep gullies have been formed all over these plateau-like downs by small water-courses, in which occasionally reefs of coarse ferruginous sandstones crop out from below the alluvial beds.

This post-pliocene alluvium belongs, as previously mentioned, to the Rakaia glacier deposits.

The Dean's range is separated from this plateau by a deep gully,

which runs for some distance between both, and exposing well the beds underlying the anamesite, and which forms its summit and southern slopes. The deposits below this volcanic rock are in every respect similar to those of Harper's Hills, consisting of white quartzose sands. They have also been converted into a hard flinty rock for about one foot from the stream of anamesite which flowed over them. This latter rock exhibits here various structures; it is sometimes more compact, in other instances porous and even cavernous. Near the junction of the last-mentioned gully with the Wai-ani-aniwha, a dyke appears near the water's edge, running up to the very summit. This, without doubt, is the channel by which the anamesitic rocks were ejected, and which here form only one large stream; they are the same age as those of Harper's Hills, closing the Malvern Hills series, and younger than the basaltic stream in the little range between the two, and by which the era of the green sands was closed.

I wish also to say a few words in reference to section No. IIIc., which passes through Mount Pleasant, consisting of quartziferous porphyry, and on the flanks of which beds of porphyry conglomerate and shales, with seams of unaltered brown coal, are exposed. As previously stated, it appears as if both of these beds were dipping below the quartziferous porphyry, but this is only apparent. They are only the remnant of beds of much larger extent, which mostly have been removed, only having been preserved where very favorable circumstances combined. These remnants abut here against the porphyry.

The rocks at the base of this remarkable outlier consist of a hard palæozoic greenish sandstone, which alternates with slaty shales, and dips N.N.W. 75°.

It is only exposed in the bed of a deep creek, the whole hill side being otherwise covered with debris from Mount Pleasant. About 500 feet above this little watercourse the porphyry conglomerate appears, forming a little hillock surrounded by recent detritus.

It consists of the same pebbles of quartziferous porphyry as that which occurs in the flat below about a mile distant, but the enclosing medium is here very ferruginous, the whole rock appearing as if it had suffered greatly from atmospheric agencies.

Leaving this little hillock and crossing a small hollow we reach the shales with seams of brown coal which have been laid open by an enormous slip which took place some years since. There are first about fifteen feet of shales visible, containing three seams of unaltered brown coal, none of which reach a thickness of two feet. For twenty

feet above this bed the hill side is covered with debris, after which we reach—

	Ft.	In.
Shale ... ... Thickness not seen.		
Brown coal (unaltered)	2	1
Gritty sandstone with impressions of stems of plants often black from admixture of carbon	2	0
Brown coal (unaltered)	0	2
Shales (micaceous and light colored with carbonaceous markings)	5	3
Brown coal (unaltered)	1	6
Shales	4	0
Brown coal (unaltered)	0	11

Above this uppermost seam small portions of shale are visible, after which only debris covers the mountain side to near the summit. These beds dip E.S.E. 36°.

On the other side of Mount Pleasant the same younger rocks appear again with the addition of the Ostrea and still younger deposits (white quartzose sands) to which I shall allude again in describing

Section, No. IV.

This section passes not only through the Upper Selwyn outlier, of which I have already pointed out the principal characteristics in giving a description of the general section No. II., but also gives us another insight into the stratigraphical relations of the oldest conglomerate beds with the chertose and diabasic rocks above or alternating with them. It is evident that there were several eruptions of the diabases with conditions favorable for the formation of small calcareous deposits (marble). This section is further very instructive in making us acquainted with the relations of the quartziferous porphyries to the older sedimentary rocks, and of which I shall give a description when treating of the sections drawn to illustrate this very interesting series especially.

Leaving these porphyries and descending towards the 1000 acre swamp we pass through the whole series of younger sedimentary rocks in the same sequence as before observed.

The porphyry conglomerates follow all the original outlines of the mountain side, and also the shales and brown coal overlying them do so to some extent. The lowest bed belonging to the latter series is

formed in Woodcutter's creek by a coarse sandstone with carbonaceous markings dipping South by West 23 °.

Micaceous shales of various shades containing seams of unaltered brown coal from six to two feet in thickness repose upon it, whilst in a small creek to the West several seams of similar character and dimensions are exposed, but dipping N.E. 8 °.

A few hundred yards lower down the former creek shales with seams of coal appear again, but standing now at a much higher angle and dipping S.E. 60 °. One of these seams containing an earthy brown coal was, as far as visible, three feet thick, but the whole formation has suffered greatly from denudation, and seems moreover to have been deposited in an irregular manner following the outlines of the spurs.

Descending still more towards the valley, quartzose sands with harder bands of limonite sandstone make their appearance, overlying the coal measures; they have been broken through by a dyke of basalt which runs from near the Hororata across Hall's creek and ends near the slopes of Mount Pleasant. It is there about fifteen feet thick and has a vertical position, and, as far as I could observe, has not had any altering influence on the rocks near it. For a long time the same loose sandy beds continue, till we reach the 1000 acre swamp, of which I have already given the principal characteristics. Section No. IV crosses it in its upper portion, where it has been filled with white silt (glacier ooze).

On reaching the other side a small hillock rises at the foot of Harper's hills, consisting of Anamesitic lava, having cooled in small hexagonal columns, sometimes slightly curved. In some portions of this hill they are arranged as the straw ropes of an old fashioned beehive. This struction is known in volcanic regions under the name of rope lava. At some other spots in the neighbourhood there are signs that powerful igneous action has been exercised upon the quartzose sands, as they appear either as hard vitrified flaggy cakes or as a thick bedded peculiarly fritted sandstone. Near this hillock the Harper's hills are intersected by a low saddle, through which the road to Hall's bush leads from the plains. The doleritic streams on the southern side of that pass are of inconsiderable thickness, they dip S. by W. 35 °.

I obtained here the following two sections within 150 yards from each other, in descending order.

Section nearest to Hall's Saddle.

	Ft.	In.
Anamesite, porous, highest bed... ...	5	0
Tufas, enclosing lapilli and ashes ...	4	0
Tufas, of a more arenaceous character ...	8	0
White quartzose sands, as far as visible ...	6	0

Section 2.

Anamesite, more compact	4	0
Sandy tufas, sometimes resembling ashes...	5	2
Anamesite	2	9
Clays, altered and burnt with streaks of vivianite	2	6
Tufas, reddish brown	4	0
White sands, as far as exposed... ..	3	6

Sections Va. and Vb. contain the details of the remarkable outlier of the Acheron which, protected by a great thickness of hard beds of doleritic rocks, has resisted so effectually the enormous power of the great post-pliocene glacier filling the Rakaia Valley for such a considerable time. It will not be out of place to give here, in short outlines, the geological history of this locality, written so clearly in the stony leaves of the magnificent sections on both sides of the deep gorge through which the Acheron flows.

The oldest rocks exposed to our view are palæozoic, sedimentary rocks having here an anticlinal arrangement. The first rocks opposite D. are shales with markings of annelids, which a little higher up the river are underlaid by bluish or dark greyish shales, identical in character with the same rock occurring all over the province, and containing the peculiar long flattened fossil with a depression running along the centre usually named by me the fossiliferous Mount Torlesse shale.

Below this rock appears a hard fine-grained greenish and bluish sandstone. Having crossed the focus of eruption in the central portion of this section, we arrive at the other wing of the anti-clinal axis, previously alluded to. First, the bluish and greenish sandstones appear, again forming a picturesque gorge, but now with an opposite dip, succeeded by the Mount Torlesse fossiliferous shales, after which we reach a succession of thick bedded, coarse, greenish sandstones with globular concretions of a more finely grained sandstone, resembling similar beds in the Amuri District. This uppermost rock before the brown coal series is reached shews how, for more than twenty feet, it has greatly

suffered from the influence of atmospheric or marine action, being decomposed in a remarkable degree.

The brown coal measures repose unconformably upon these palæozoic rocks without any porphyry conglomerate between them. The former consist of twenty feet of black shales with several small seams of coal changed to anthracite, and of a thickness of two to fourteen inches; the main seam of an average thickness of four feet two inches follows next. It is very pure throughout, and has been changed by the action of the dolerite principally close to the channels of eruption, to a fine anthracitic coal. It dips in the locality where Mr Oakden obtains his supply of coal N.N.W. 39°., whilst near the dolerite stream it shews together with the shales a false stratification dipping apparently W.N.W. 70°. This seam is covered in ascending order by about seven feet of black or iron grey shales; eight feet of loose sands colored black by carbon; twenty-four feet of dark colored shales, which for the last ten feet before we reach the dolerite have been greatly altered so as to assume a greyish white color and the character of a porcelain jasper, but still preserving the markings of obscure remains of plants enclosed in them. These beds following generally the surface outlines of the palæozoic rocks appear in several localities as isolated patches from below the morainic accumulations or the post-pliocene alluvium, together forming the upper deposits of the whole district. In the upper portion of the valley close to A no large seams are visible, and only three small ones of one, three, and five inches appear between the shales.

Upon them repose ferruginous and sulphurous sandy clays, in which some large specimens of *Ostrea*, *Lucina*, and *Panopœa* appear, the two latter as casts are imbedded. These sands are intersected by two beds of limestone, each about nine inches thick, which consist almost entirely of a conglomerate mass of a bluish black oyster-like shell. They are separated by six inches of shales covered with an efflorescence of sulphur, whilst they are coated on both sides with a crust or crystals of gypsum. Upon them repose beds of porcellanite at the contact with the dolerite.

The coulées of this volcanic rock are here of great thickness, forming on both sides of the valley a hill several hundred feet high. Three distinct centres of eruption can be observed, of which the central one has formed two channels, passing, as far as visible, only through the carboniferous series. These two channels unite about 100 feet above the valley, and have raised a portion of the coal-bearing

beds enclosed between them, as well as the Southern portion of the same series close to them.

The dolerite at D is greenish, and has the structural appearance of the igneous rock from the drives at the Selwyn and Kowai ; where in contact with the palæozoic slate-clored shales it has hardened them and bleached them to a whitish jasperoid rock. The volcanic rocks of this district, forming the upper portion of the whole series, consist of a succession of brown tufaceous doleritic beds, with streams of dolerite alternating with them. The latter rock has a very porphyritic or even granitoid structure, and presents a fine appearance. Mesotype and some other Zeolites occasionally fill the cavities in them. I have stated already my belief that the felspar in some of these rocks will prove to be Nepheline.

Although the coal in this locality is confined to a small area, having probably been only preserved where the dolerites occur near or above it, it will nevertheless be in sufficient quantity to satisfy local wants for many years to come, the more so if that portion of the country remains as sparsely populated as it is at present.

The remaining sections, which illustrate mainly the relations of the melaphyres and quartziferous porphyries with the older rocks, need scarcely in that respect any verbal description, except in perhaps pointing out some of the most remarkable places of contact.

It will be observed in comparing the sections with the geological map, that beginning at the Gorge of the Rakaia the melaphyres form the centre, whilst generally on both sides of them the quartziferous porphyries occur. I have, as I think, previously stated that pitch stones indicate either the contact in the channels by which the younger acidic rocks were erupted, or when in some instances the place of contact could be traced where they are covering older basic rocks.

Whilst the melaphyres have altered to some degree the palæozoic sedimentary beds close to them, of which there is an instructive section near the summit of Philips' Range, the acidic rocks seem not to have been able to produce such effect. This is principally judging from the dykes where they are passing through the palæozoic strata, as well as from the Gate Creek outlier. This small isolated system sends forth four distinct dykes, which form a fine illustration of what I previously stated, the only effect being, as far as I could see, that the sedimentary rocks are broken up in much smaller polyhedric fragments than those of the same nature which stand further off the line of contact.

However, near the summit of Philip's Range and some other

localities, where the quartziferous porphyries repose upon the sedimentary rocks, the latter are much decomposed and altered, but, doubtless, only from having been subjected for a long time to powerful atmospheric or marine action upon them, and that the melaphyres in their turn were effected by the same agencies is well exhibited in several localities where the porphyries repose upon them, and of which amongst others, section VIa., at D., gives a clear illustration.

The melaphyres are here decomposed to a reddish-brown crumbling rock near their contact, and the same is well exhibited south of Snowy Peak in a deep gully, where a small stream of quartziferous porphyry, sometimes with quite a tufaceous appearance, lies upon the older melaphyres. The basic rocks east of High Peak, continue to show the same characteristics as in Snowy Peak, viz., an older amygdaloidal rock decomposing easily, being crossed by numerous dykes of a sometimes fine-grained almost doleritic-looking rock, of which at A. in section No. VIa., a fine example occurs on the summit of the hill, and which, doubtless, passes also in a dyke-like form through the sedimentary rocks below, but which, in order not to fill the section with details, I could not directly observe, I have omitted to indicate.

The section No. VIII. deserves, however, more than a passing notice, because, besides shewing us the junction of both eruptive series, it gives us the details of the newer sedimentary beds reposing upon them.

From a careful examination of that locality, there is not the least doubt that the quartziferous porphyries of Pullwool Peak cover the melaphyres, which form the gorge of the Hororata, and which have the appearance, not only of a dyke, but of having tilted up and folded the younger sedimentary rocks near them. The latter, however, were simply deposited in little steep bays, entering between the spurs of the hill, composed of melaphyres, and capped by porphyry. These sedimentary beds are at the same time continuous, following the base of that hill in all its sinuosities, although the section might suggest that they were deposited in two separate basins. A slip on the hill side has at one spot exposed the lowest stratum of the coal-bearing series, proving that it reposes upon the decomposed flanks of the melaphyres. It consists of a tufaceous bed, made up of fragments of disintegrating melaphyre. In fact, it is rather difficult to fix exactly the spot where the decomposing melaphyre ends and the tufa begins.

Near the quartziferous porphyries in the same section the lowest beds above them are tufas derived from the disintegration and decom-

position of these acidic rocks. They are about forty feet thick, and gradually change into shales with beds of fire-clays the whole having a total thickness of twenty feet. Above them the following strata appear:—

	Ft.	In.
Brown coal (unaltered)	1	6
Shales	0	6
Brown coal	1	2
Shales (black)	0	8
Shales of lighter colors (banded) ...	8	0
Brown coal	0	7
Shales	2	2
Brown coal	2	2

Upon them repose micaceous shales about fifty feet thick, and containing concretions and layers of clay iron-stone. Some of these latter have sometimes a thickness of two feet six inches, and will one day be of value for smelting purposes. The micaceous shales form here the uppermost beds visible. Indications of the same series of coal-bearing rocks occur in several localities higher up the creeks, all along the base of the eruptive rocks containing small seams of brown coal of excellent quality (pitch coal), but generally dipping at high angles, and having, at least, for the present no commercial value.

Below the melaphyre gorge, the banks of the Horórata are formed on both sides by post-pliocene alluvium and morainic accumulations for half a mile, after which we reach an outlier of palæozoic sedimentary rocks, probably a continuation of those occurring on Yorkies Pass between Pullwool Peak and Mount Pleasant. This outlier consists of sandstone, clay slates and shales, similar in character to the beds overlying the conglomerates previously described. The contact of the younger beds with the older sedimentary rocks is not visible, however the space between the latter and the coal bearing series is so small that if beds of porphyry conglomerate should be found existing, they can only be of inconsiderable thickness. The strata in the banks of the river follow each other in an ascending series, as under

	Ft.	In.
Shales with carbonaceous markings ...	10	0
Impure brown-coal	1	0
Dark fissile shales	1	6
Impure brown-coal	0	9

	Ft.	In.
Shales, light colored with carbonaceous markings, alternating with darker layers	3	6
Brown-coal, impure and irregular ...	0	10
Shales, micaceous light colored... ...	10	2
Shales, black	1	0
Impure brown-coal	0	8
Micaceous shales	18	0
Quartzose sands, ferruginous	12	0
Quartzose sands, mottled	8	0

This is the last bed of the series open to our examination. The post-pliocene alluvium, covering entirely for about fifty yards the hill side, and forming steep cliffs against which the river washes, after which sandy glauconitic clays appear. They are generally of a bluish color, but when decomposing assume rusty tints. Separated in several beds by strata of a peculiar micaceous limestone, they also contain large concretions often in the form of Septaria of similar character, both deposits containing veins of calcareous spar. These calcareous beds are of considerable interest as they contain a great assemblage of fossils belonging both to the vertebrate and invertebrate divisions, such as bones and teeth of Saurians (unfortunately in very fragmentary conditions, and, as far as observed, rolled), scales, bones and teeth of fish, (*Lamna*, *Otodus*, *Hybodus*) ; the following genera of Mollusks are also represented, *Dentalium*, *Turitella*, *Fusus*, *Cypræa*, *Dosinia*, *Lucina*, *Anatina*, *Panopœa*, *Tellina*, and some others.

Upon them repose green sands of such dark greenish tints that they appear almost black, changing gradually into a more yellowish color. This is the uppermost bed visible in that line of section, post-pliocene alluvium and glacier deposits forming from here the banks of the river to its junction with the Selwyn. These strata, as described, are the representatives of the series lying east of the Cairn Range, but which is here much narrowed in its dimensions.

The sections Nos. IXA to IXF have been drawn in illustration of the interesting geological features of the Rakaia Gorge, which I examined from one end to the other by following the banks of the river nearly all the way through, crossing the headlands where the passage near the water's edge was found impracticable.

What strikes us first in looking at the two general sections is the fact that the older melaphyres seem to lie in three of the four points

of junction upon the younger quartziferous porphyries; however, this may only be apparent because I could not reach the three localities in question quite closely, and could only examine them from the opposite side of the gorge, but the first point marked A in section IXF was accessible, and here the position of both rocks shewed clearly that the acidic were overlying the basic rocks.

Descending the gorge on its left or northern bank we pass a series of palæozoic sedimentary rocks, sandstones, and shales, the latter containing the peculiar fossil of the Mount Torlesse shales. These beds are here crossed by a dyke and overlaid by a stream of fine grained dolerite.

The junction of the porphyries with these sedimentary rocks is almost entirely hidden by debris, but not concealing altogether the occurrence of a fine selvage bed of black garnetiferous pitch-stone at the junction. It would also seem from what is visible at that junction that the quartz porphyries underlie the palæozoic rocks—this is, however, not the case, as the former have flowed over them toward the gorge, by which this appearance has been brought abo ut.

I have already alluded to the enormous thickness of the melaphyres, and that they have often the character of Amygdaloids, Tufas, and Agglomerates, the whole being intersected by numerous and often large vertical dykes of a finely grained melaphyre.

Some of the Amygdaloids are full of concretions of green earths, Semiopal, Chalcedony, and calcareous spar. The whole suggesting that we have the orifice of a submarine crater before us, possessing a longitudinal shape, and which gradually was filled up before the quartziferous porphyries were ejected.

I wish to point to another interesting spot—the only one where tufaceous beds appear below the acidic rocks, viz., to the second island in the gorge of the Rakaia. I may also mention that on the left bank of the river, opposite to this island, a small outlier of palæozoic sandstone appears, almost hidden under alluvium, but surrounded everywhere by quartziferous porphyry. The actual junction of both series is, however, not visible.

Having passed the first island, consisting of quartziferous porphyries, which also form the high perpendicular walls on both sides of the picturesque gorge, we reach, in ascending the river on its right bank, a small cliff or islet, falling abruptly to the water's edge on the eastern, and surrounded on its western side by shingle, the Rakaia having here a flood channel. This islet consists principally of tufaceous beds, which

have a horse-shoe arrangement, the bed No. 3 of the section No. IXe being continuous towards the north, and dipping in the centre, west 68°. The lowest bed, for about ten feet visible, is a light-colored shaly tufa with carbonaceous markings. Upon it repose marly tufaceous beds of a greyish color, and with similar markings, but containing also peculiar seams of impure lignite, of which one is about ten inches thick. The next bed, No. 3, consists of a yellowish or greenish white tufa, enclosing sometimes large drift trees, the interior of which is changed to flinty chalcedony or woodstone, whilst the bark appears as a white, mealy, silicious substance. The next bed, No. 4, is also tufaceous, and of the same character, but it contains a great many lapilli, mostly small pieces of quartziferous porphyry, pieces of felstone, sandstone, and slate, such as they occur at present in our Alps, as well as pieces of melaphyre; amygdaloids are also found in the same tufa. The bed No. 5 is still tufaceous, but it contains already numerous specimens of garnets in grains and occasionally in crystals, whilst the uppermost bed, No. 6, is a true quartziferous porphyry of a vivid green color. There are, however, in some hand specimens of both beds (Nos. 5 and 6) so many resemblances which make it almost appear that even the latter No. 388 is still of tufaceous origin, and which the appearance of several other porphyritic rocks from Philip's Range also suggest. I mean to say that some of those porphyries appear to have cooled under peculiar circumstances, which are not quite clear, but exclude the belief that they are simply of purely igneous origin.

I have already given a short general description of the tufaceous and carbonaceous beds which fill up the depression in the centre of the melaphyres, and shall now proceed to give some details as to their sequence and lithological character. They have generally a synclinal arrangement, although both general sections might suggest that they abut against portions of the underlying melaphyres. This is, however, only apparent, because these sections, in following the course of the river, cut transversely through them, and do, of course, not shew the eruptive rocks, which lie further back.

On the northern side of the river, above Bryant's Hill, the lowest beds consist of shales and conglomerates, with layers and concretions of clay iron-stone, dipping N.N.W. 46°. Two beds of black shales, each about ten feet thick, are here separated by fifteen feet of conglomerate, containing each several small seams of glance coal, with a black streak, of which the largest is fifteen inches thick, whilst the greater part vary from one to three inches. They are overlaid by a great thickness of

conglomerates, shales of lighter color, with carbonaceous markings, and with drift wood, changed into pitch and sometimes into glance coal, enclosed in them. Deposits of clay iron-stone continue to be present. Although this conglomerate reposes, as far as exposed, only upon basic rocks, it is composed almost exclusively of well rolled boulders and pebbles of quartziferous porphyry. There are only occasionally a few small pieces of older sedimentary rocks and melaphyres amongst them. In the light-colored shales there are indistinct markings, as if of aquatic plants (sedges and rushes).

On the opposite side of the river a large stream of dolerite has broken through, and reposes unconformably upon these younger sedimentary beds. The shales in contact with these igneous rocks have also been altered to a whitish coarse porcellanite with a false stratification, apparently dipping S.S.W. 74° parallel to the plane of the dyke's lower face; whilst a little further on the less altered beds exhibit their natural stratification, and dip S.W. 23°.

The following beds were noted by me in descending order near the contact:—

	Ft.	In.
Sandy shales, altered to coarse Porcellanite	6	0
Shales, altered with indistinct remains of plants	7	0
Anthracite	1	9
Black Shales	0	6
Anthracite	0	5
Gritty sandstone with pieces of drift coal	2	3
Marly shales, with indistinct markings of plants	9	7
Gritty sandstone	1	0
Some of these sandstones when in contact with the dolerite stream have been fretted in a most remarkable manner.		
Porphyry conglomerate	11	0
Black shales	1	0
Coal, anthracitic	1	7
Shales, with their partings of coal ...	0	3
Coal, anthracite	0	7
Shales, with small seams of coal generally less than one inch thick	6	6
Porphyry conglomerate	30	0

Below this last mentioned bed there occurs a succession of light sandy or marly shales, gritty sandstone, porphyry conglomerate, and clay iron-stone, alternating with each other for at least 300 feet, but no more seams of coal or even black shales appear amongst them.

The gritty sandstone is sometimes of an iron rust color, and becomes often so ferruginous that it may be called a limonite. Sometimes huge trunks of trees are enclosed in these beds, the thick bark altered to clay iron ore, whilst the centre has been changed either into wood-stone, or is filled with a black shaly mass. I measured one of these trees, which was sixteen feet long and two feet in diameter. The beds of the porphyry conglomerate are of the largest dimensions in the series, sometimes thirty to forty feet thick, whilst the other beds vary between two and ten feet.

In retreating from the dyke the coal becomes less and less altered until it appears only as a pitch coal of fair quality. As we ascend the river along the southern bank the beds of black shale and coal gradually thin out until they disappear altogether before we reach the melaphyres upon which the whole rests. From the foregoing notes it will appear that practically the beds of coal in the Rakaia Gorge, although containing generally altered coal of good quality, are too thin and too inaccessible to be of much value to the country. It is true that there are

2 feet 2 inches of anthracitic coal separated by
0 „ 6 „ of black shales.

---

2 feet 8 inches, and
2 feet 4 inches of anthracitic coal separated by
0 „ 3 „ of black shale.

---

2 feet 7 inches, which could be worked.

However, the seams would have to be opened near the bed of the river, and the coal would have to be lifted five to seven hundred feet before it could be placed in the railway trucks or made available for any other mode of transport. And even if this difficulty could be overcome it appears that the basin is too small in extent to contain a great quantity of coal of good quality.

This Report having reached already much larger dimensions than I think desirable for publications of this kind, I must defer more details, collected during my exploration of the district under review, and which are of a purely scientific character, for a future occasion.

And if I have been obliged in some instances to enter rather fully into details, I trust they will be acceptable to the student, who will still find in the Malvern Hills and their neighbourhood a rich field for further researches.

In summing up the results obtained during this survey, I may state my conviction that, although the sanguine hopes of some portion of the community have not been realised, there is still sufficient ground for congratulation. There is a limited amount of altered brown coal at once available, with lime stones of excellent quality, cement stones, and clay-iron ore. Besides the unaltered coal in isolated patches, an almost unlimited quantity of brown coal of good quality is also at our disposal, and I can really not see any reason why it should not be extensively used for houeshold and steam purpôses in the same manner as obtains on the continent of Europe.* We have also an almost inexhaustible supply of fire clays and fine quartz sands for the manufacture of fire proof pottery and of glass, which one day will certainly be useful to the whole district.

If all these resources are properly developed, I feel confident that in years to come the industries called through them into existence will give new life and activity to this portion of New Zealand, and thus largely contribute to the sound prosperity of the whole Colony.

IV.

Table of Altitudes.

The altitude marked with * have been ascertained by the spirit level through the Public Works Department; the rest have been calculated from barometric observations.

	Feet.
Big Ben, highest summit of Thirteen-mile Bush Range	5224
Brown coal beds behind Big Ben, where the creek cuts through the main seam ...	2891
Summit of dolerite ridge above it ...	3160
Porter's Pass...	*3097
Foot of Porter's Pass	*2060
Lake Lyndon...	*2743
Junction of Kowai with McFarlane's Stream	1787

* In 1868 there was raised in Prussia, 22,700,000 tons of true coal, and 5,600,000 tons of brown coal. In Austria, 3,372,650 tons of true coal and 2,976,850 tons of brown coal, and the latter is rapidly superseding the hard coal for all purposes in some districts.

	Feet.
Kowai coal measures, drive's entrance ...	1424
Kowai, where West Coast Road crosses ...	1393
Kowai Corner, McRae's	*1274
Junction of Kowai with Waimakariri ...	1003
Gorge Hill, lower end on plains (lagoon) ...	886
Little Race-course Hill, summit... ...	980
Russell Hill, summit	2752
Abner Head, summit	2231
Wai-ani-aniwha, where it enters the plains	797
Basalt ridge, between Selwyn and Wai-ani-aniwha	1192
Upper Acheron, Flat, junction of two branches	1684
Snowdon (verandah)	1664
Shoulder of Fighting Hill, over which the road crosses	1737
Upton's Flat (verandah of house) ...	1383
Wether Range, left bank of Selwyn ...	2516
Hart's Coal Pit	1015
Lowest saddle above Hart's Coal Pit to Wai-ani-aniwha	1162
Cairn Range, summit	1608
Precipice Point, Selwyn	964
Little Rocky Hill, above Precipice Point ...	774
Mr. Hill's Home Station (verandah) ...	1147
Mount Misery, summit	2342
Mount Pleasant	2116
Yorkie's Pass	1563
Pass between Pullwool Peak and Rocky Peak	1687
Rocky Peak	2763
Rockwood Home Station (verandah) ...	1370
High Peak	3019
Snowy Peak	2983
Saddle between High Peak and Snowy Peak	2491
Hill's Pass to Upton's Flat	1816
Four Point Range, summit	2620
Harper Hill, summit	1334
Harper Hill, termination near Selwyn Bluff	770
Entrance of Surveyor's Gully into plains ...	*865
Windwhistle House	1512

	Feet.
Bed of Rakaia, near Island Ferry, lower end of Gorge	775
Bed of Acheron, where road crosses ...	1290
Flag-pole Hill	3016
Curiosity Shop beds, near level of Rakaia	651
The Hon. John Hall's Station	765

NOTES ON THE GEOLOGY OF THE GLENTUI, A BRANCH OF THE RIVER ASHLEY, PROVINCE OF CANTERBURY.

BY JULIUS HAAST, Ph.D., F.R.S.

14th November, 1871.

THREE miles below the Gorge, where the River Ashley enters the Canterbury Plains, a small creek named the Glentui joins it on its northern banks, running nearly during its whole course in a deeply cut gorge. This creek for about four miles passes through a successio of young palæozoic sedimentary rocks, identical in character with those observed in the Malvern Hills, and described in a report to accompany the Geological Map of that district.

These palæozoic rocks stand also here at a very high angle, and their strike and dip vary considerably in their short distances.

The lowest beds visible are conglomerates consisting of small pebbles of sandstone. Calcareous sandstones and shales with this peculiar fossil (Annelid of Mt. Torlesse) follow, upon which a series of strata repose, consisting principally of diabasic and chertose rocks.

The latter are separated by a large thickness of greyish and greenish sandstone thickly bedded with calcareous coatings and strings of noapyrites, and possessing sometimes a brecciated structure from another series of diabasic beds and cherts with kernels and small strings of limestone, alternating several times with each other, having a thickness of about one hundred feet, and possessing a synclinal arrangement.

About thirteen chains above the gorge, where the Glentui cuts through the dolerite streams, these palæozoic rocks disappear below a series of green sands alternating with white quartzose sands, which form sometimes enormous slips, under which, about one chain from the junction, a dyke or stream of this peculiar greenish dolerite appears identical in lithological character with that from the Malvern Hills, where it is associated with altered coal seams.

The true relations of this dolerite in this locality could however not be made out, by far the greater portion being covered by enormous slips.

These younger beds abutting against the older rocks fall towards the east. In the white quartzose sands lenticular shaped masses of various dimensions, consisting of micaceous sandy shales, like those of Mr. Hart's mine in the Malvern Hills, occur, containing nests and pockets of coal. The latter is brittle, has sometimes a black streak, and seems to have undergone considerable alterations, without doubt caused by the influence of volcanic action in close vicinity.

Sometimes small nests of coal (driftcoal) lie amongst the white sands without any shale associated with them.

For about ten chains the same white quartzose sands, sometimes more or less glauconitic, and generally not exhibiting any stratification, continue to form the banks of the river.

Before we reach the dolerite streams, by which this series is closed, it sometimes assumes the character of sandy clays, ferruginous and with incrustations of sulphur, closely resembling similar beds in the Malvern Hills and the Waipara.

Before the dolerite streams were deposited above them, they must have suffered considerably from denudation, as the streams stand at an angle of 78°.

The lowest coulée of dolerite is very ullular, and has a thickness of six feet. Upon it repose whitish sands four feet thick, which are covered by a second stream about five feet thick with an amygdaloidal structure, the pores and cavities being lined with Spherosiderite. This stream is again covered by white sands which gradually change into true dolerite tufas of light reddish brown tints, the whole about ten feet thick. The uppermost stream has a thickness of about twenty feet, being scoriaceous at bottom and top, and more compact in the centre.

The larger cavities in this latter are filled up by pitchopal, which sometimes becomes very ferruginous.

These three streams resemble in texture and structure closely the lava-streams of Harper Hills and Dean's Range of the Malvern Hills.

They form also here the uppermost beds of the whole series, and from here only large masses of post-pliocene alluvium continue to the junction of the Glentui with the Ashley. How great the erosion has been here is best shown by observing that even the hard doleritic

rocks are everywhere covered by the post-pliocene alluvium forming the Canterbury plains.

Another small creek, flowing in a very deep gorge, joins the Glentui a few chains below the dolerite gorge on its left bank. This creek also cuts through the dolerite streams, standing here nearly vertical, and in a very narrow gorge with perpendicular walls on both sides, and more than 200 feet high.

Between the two creeks a narrow ridge runs towards the ranges, which in its lower portions consists of quartzose sands whilst the summit is covered by blocks and fragments of a thick-bedded fossiliferous limestone, consisting mostly of pieces of a white, thick bivalve shell (Ostrea?). It was, however, nowhere possible to find this rock *in situ*, so that I could not ascertain its true position and stratigraphical relations. The examination of this portion of that district is very difficult, as the whole is covered with forest and dead undergrowth, which form together an almost impenetrable thicket. This description of the younger beds applies to the left bank of the Glentui, but those on the right bank, in all principal characteristics, if we except the occurence of the older dolerites, which do not appear, are identical, but still more hidden by post-pliocene alluvium or slips.

A few chains below the junction of the younger with the older series, Messrs. Richardson and Co., of Ashley Gorge, had a drive excavated in order to see if the small seams or nests of coal were indications of larger ones, of which section No. 4 gives the details.

However, an examination showed clearly that some of the pockets in the banks near that drive had already disappeared before they reached the water line, whilst others appeared in their stead, but none of sufficient thickness or assuming such character, that we might believe in their continuity or practical value. Moreover, the drive proved that the beds had not only an anticlinal arrangement, but were abutting apparently against the older rocks. Under these circumstances I would neither recommend the continuation of the works undertaken, as they would lead to no practical result, nor the opening up of new trial works in any other locality near, as everywhere no indications of the presence of regular coal seams could be detected.

Concerning the age of these beds I can only state that I did not obtain any fossils which would give any reliable information in that respect, the only fossils being enclosed in the limestone, but too fragmentary for identification. However, I think that they represent the

brown coal series of the Malvern Hills, but this and some other points of importance can only be settled by a continuation of this survey over the neighboring district. I also visited the gorge of the Ashley for the purpose of ascertaining if coal-bearing strata could be traced there.

The only rocks visible being the younger palæozoic sedimentary strata, upon which the post-pliocene alluvium reposes, I could not recommend any trial works to be undertaken, as the Glentui beds did not offer the least evidence where *workable* brown coal seams could be expected in the neighbourhood. I have added to these notes four sections showing the relations of the different formations as they are visible in the Glentui and its immediate neighbourhood, to which I beg to refer.

Since the above notes were written I have received further communications from Messrs Richardson and Co., from which it appears that when following the largest seam or pocket of coal near the drive, Section No. 4, at (x) in Section No. 2, where the strata dip W. 50°. this seam not only very soon dips at a much steeper angle, so that after a few fathoms it stands perpendicularly, but actually immediately afterwards turns to the East, without however becoming thicker or assuming a more promising character.

We thus have proof of great disturbances by which these beds have actually been bent over and reversed.

TITLE. ion of Rockwood and Potts' Creek to one mile below
ith Hororata River. N. 30 W. to S. 30 E. Scale,
ch, horizontal and vertical. Datum line, 1000 feet.

REDUCED northern side. 5300 feet to 1 inch, horizontal and
n line, 100 feet. General direction, N.W. to S.E.
southern side. 5300 feet to 1 inch. Datum line,
al direction, N.W. to S.E
ross Rakaia Gorge. N. 45 E. to S. 45 W. Scale,
ch, horizontal and vertical.

SECTION I. aia Gorge. N. 45 E. to S. 45 W., near Dolerite
Scale, 1000 feet to 1 inch, horizontal and vertical.

II. aia Gorge, across Porphyry-tufa Island. N. 33 E.
ale 1000 feet to 1 inch, horizontal and vertical.

III. ss Rakaia Gorge, N. 45 E. to S. 45 W. Scale,
ch, horizontal and vertical.

IV. e Rakaia. Junction of quartziferous porphyry over-

IA. mit of Thirteen-mile Bush Range to Upper Rakaia
o W.

IB.

IC. ERN HILLS DISTRICT.

NS IA. AND IIA. (Geological Formations).

IIA. palæozoic.

IIB. more or less altered.
s often cinder-like.
or tufaceous.

IIIA.

IIIB

recent deposits.

IIIC. ERN HILLS DISTRICT.

IIID. SECTIONS (Geological Formations).

IIIE. .

VA. kaia desposits in Malvern Hills).

VB. tertiary.
ing streams and coulées.

VIA. al.
ds.
mes porphyritic, generally contemporaneous with

VIB. rtzose sands.
rtzose sands, covered by post-pliocene alluvium.

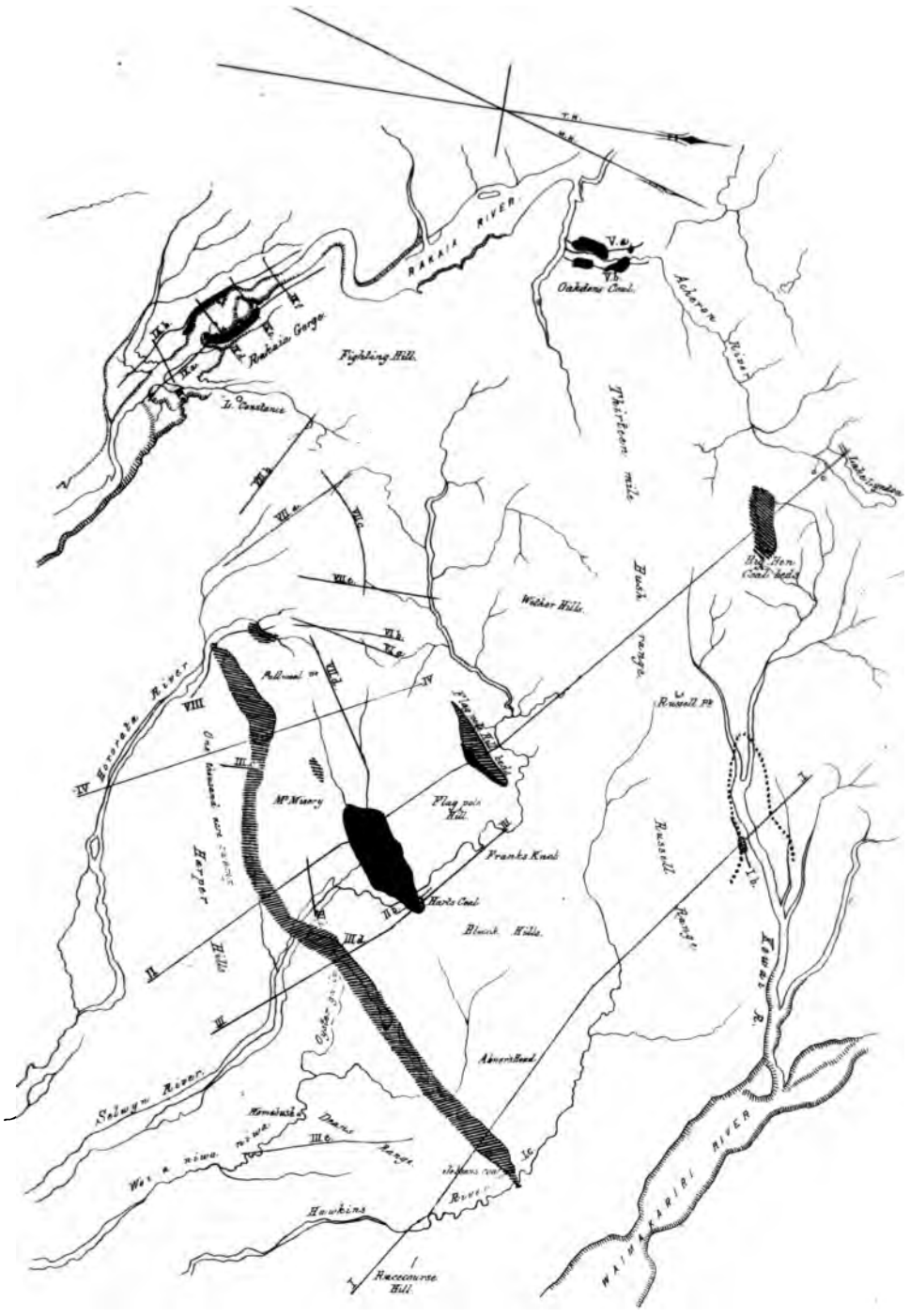
VIIA. older quartzose sands, with saurian remains.
red by dolerites.

VIIB. h remains of plants.
ls and fire-clays.
h shales and seams of brown coal.

VIIC. h shales and seams of brown coal, altered.

VIID. d young palæozoic.
ds.
th 23.

VIIE. ones, and shales, with impressions of ferns.

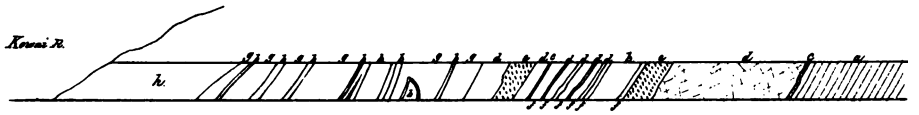


MALVERN HILL DISTRICT

CANTERBURY.

Showing position of Geological Sections described in Dr Haasts Report.

● *Areas of altered Coal.* ● *Areas of brown Coal.*



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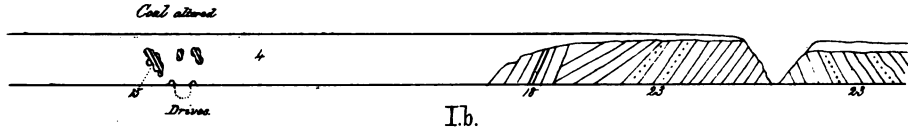

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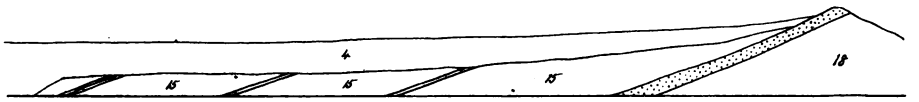
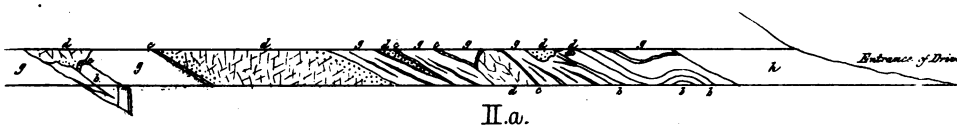
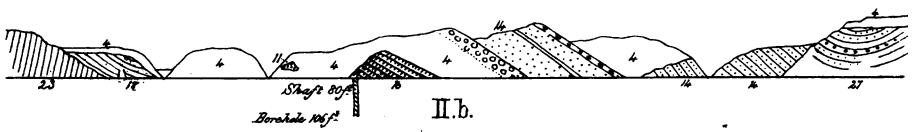


I.c.



II.a.



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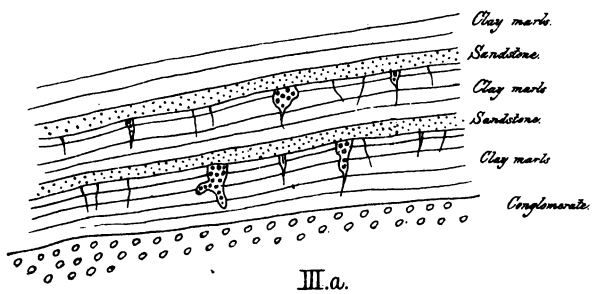

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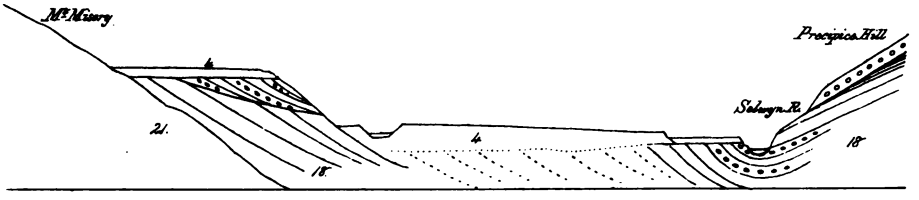

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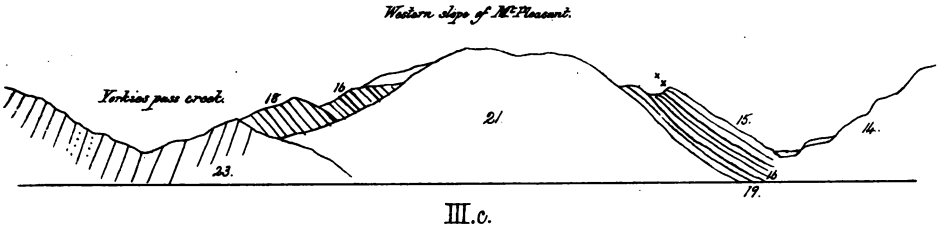

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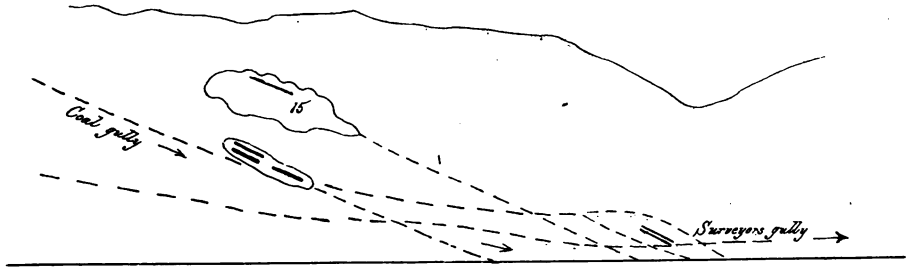

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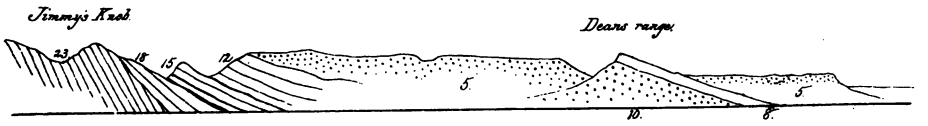

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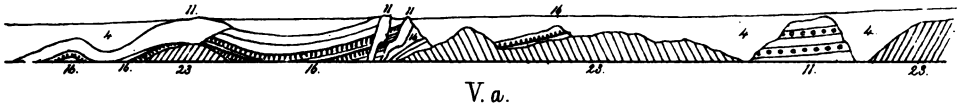

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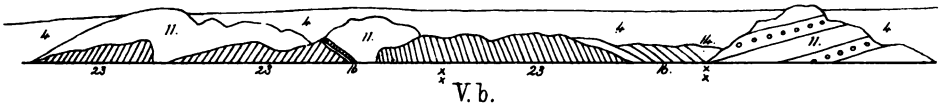

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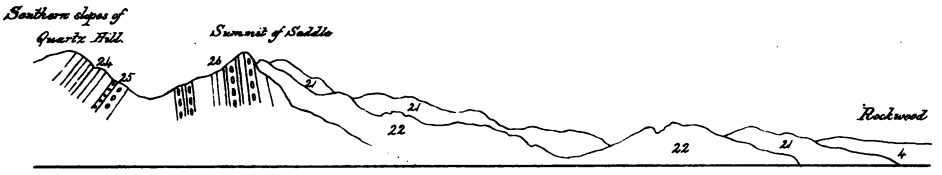

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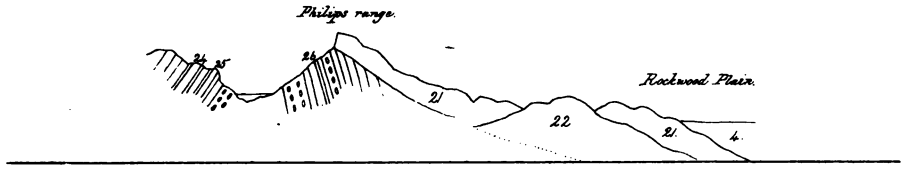

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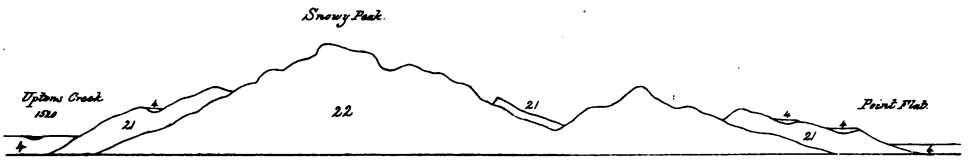

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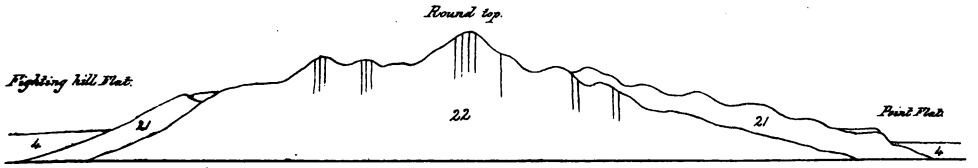

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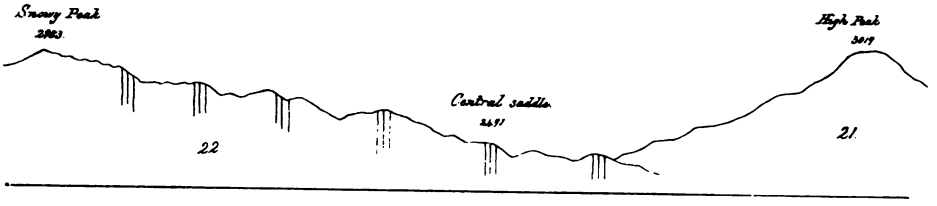

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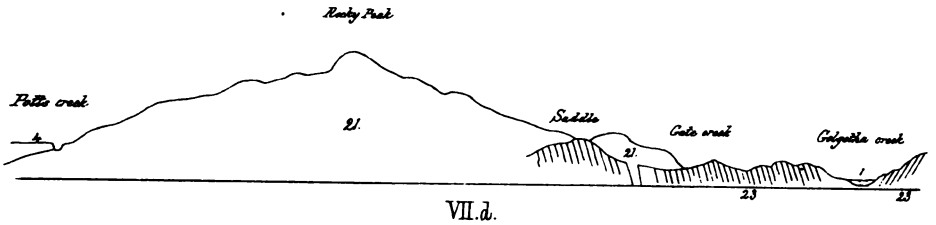

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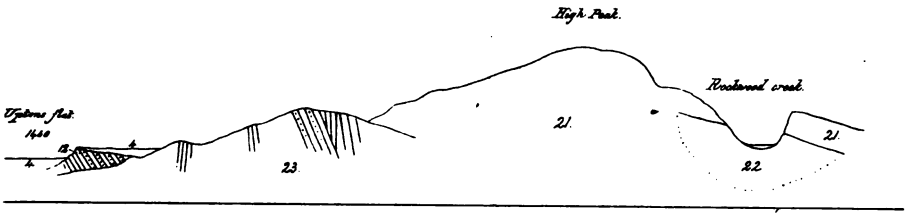

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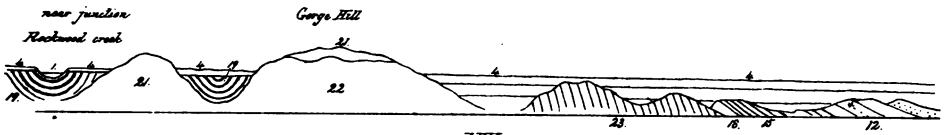

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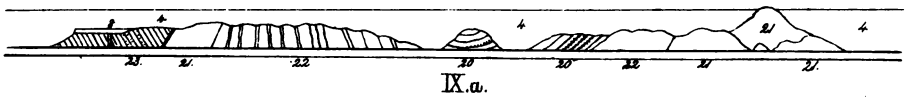

IX.a.

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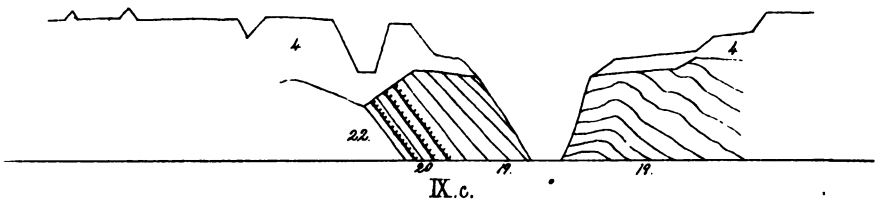

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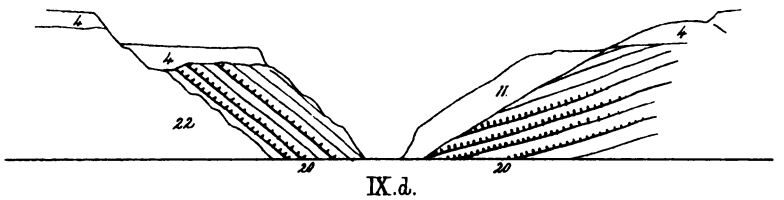

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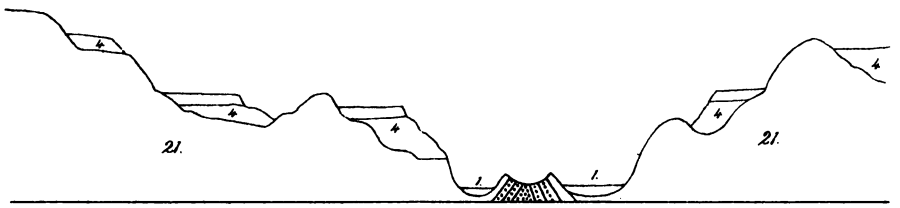

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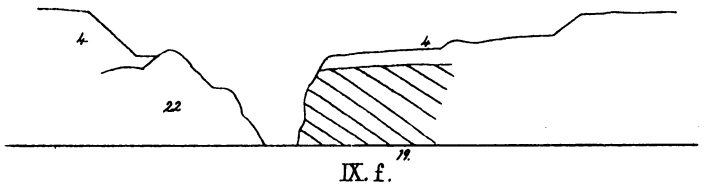

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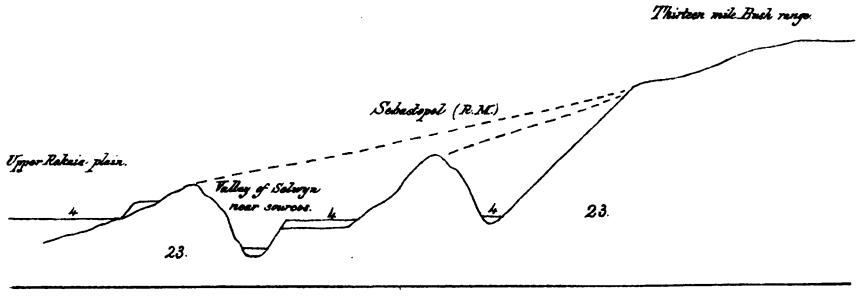
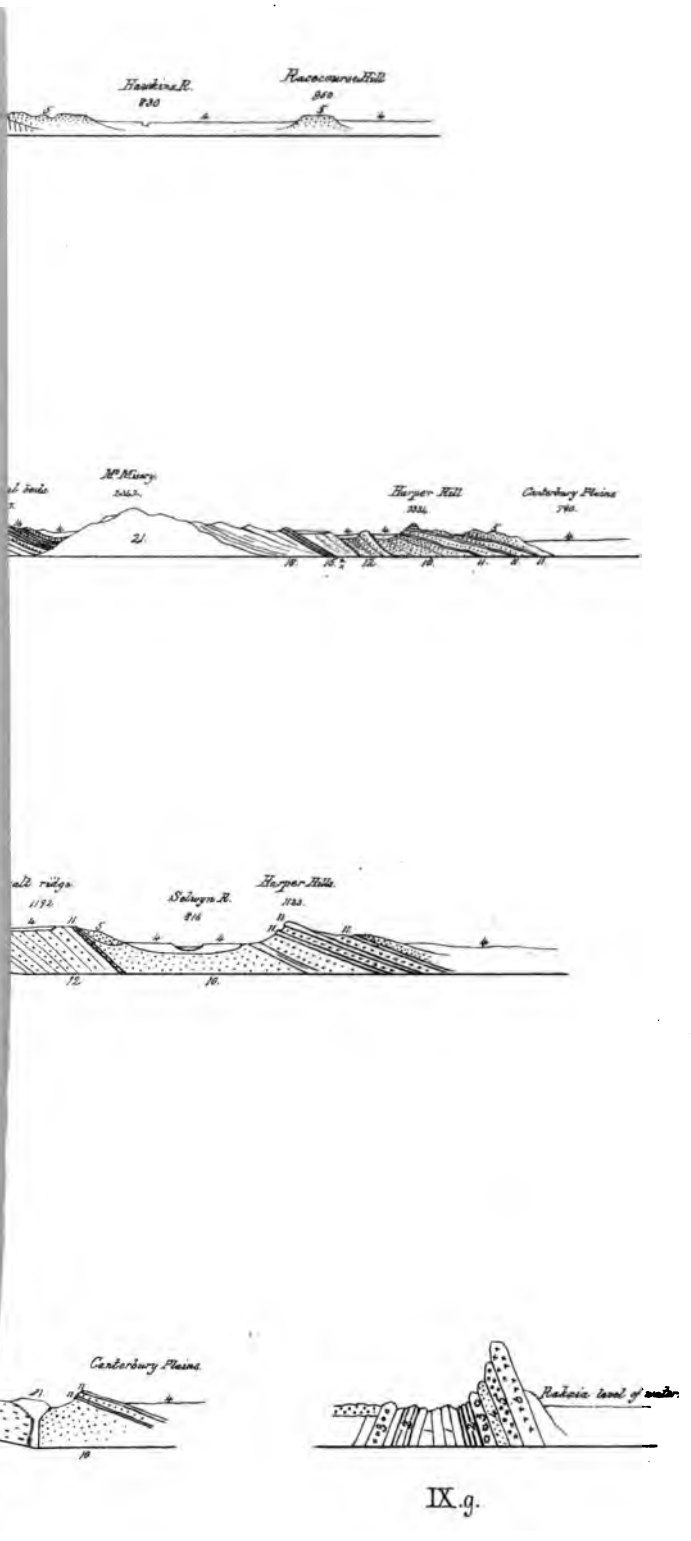


X.


Hawkins R.
930
Racecourse Hill
940
Mt Misery
3463.
Harper Hill
3334
Canterbury Plains
760.
21.
Solway R.
816
Harper Hills.
3133.
12.
10.
Canterbury Plains.
Radiola level of water.

IX.g.

TITLES OF SECTIONS ILLUSTRATING THE GEOLOGY OF THE ASHLEY DISTRICT.

REDUCED AND LITHOGRAPHED, FROM DRAWINGS BY DR. HAAST, F.R.S., BY J. BUCHANAN, DRAFTSMAN TO THE GEOLOGICAL SURVEY.

PRINTED AT GENERAL GOVERNMENT PRESS BY J. EARLE.

SECTION I.—Along left bank of Glentui from N.N.W. to S.S.E.

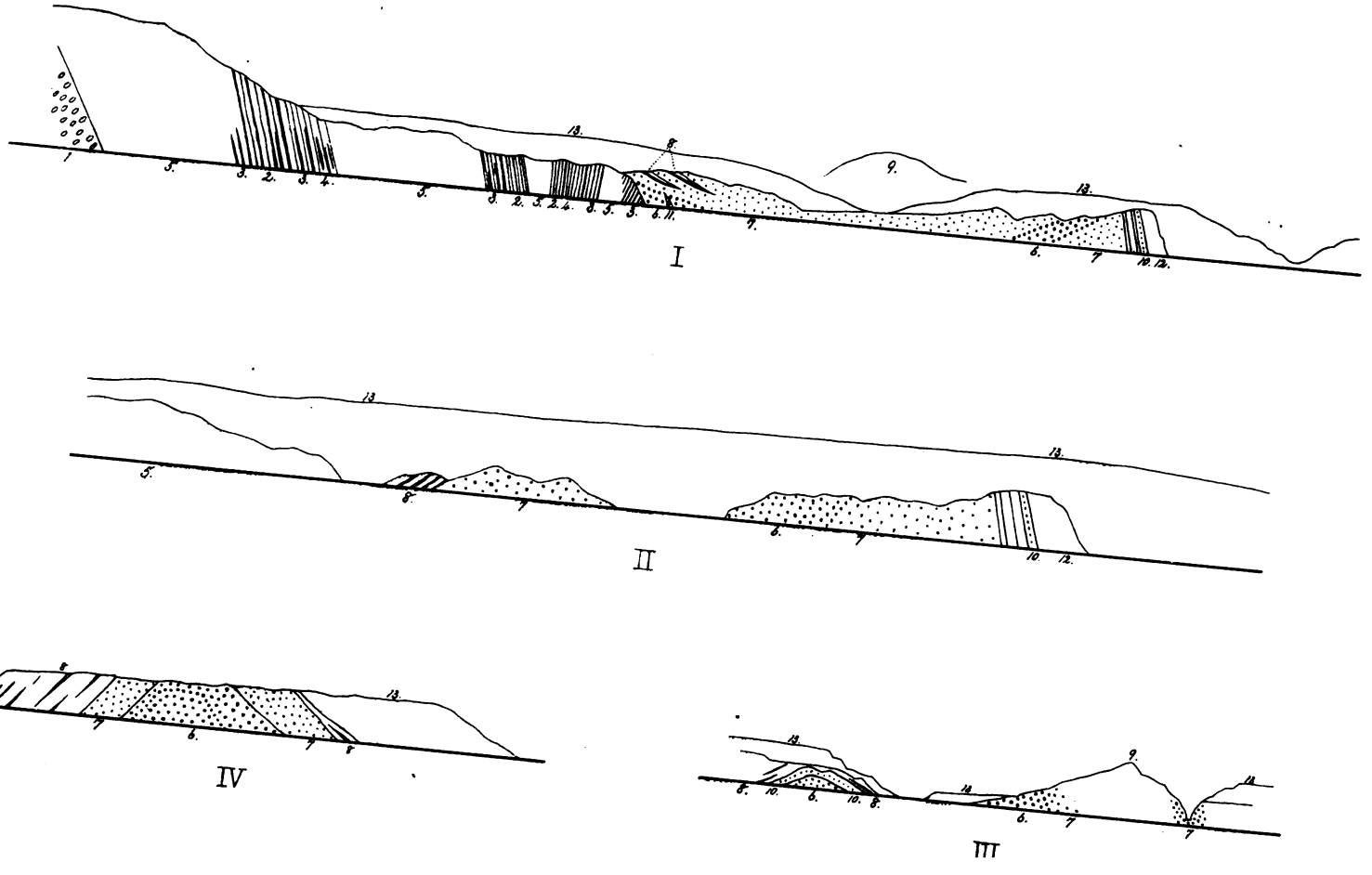
II.—Along right bank of Glentui from N.N.W. to S.S.E.

III.—Across Glentui and Dyke Gorge W.S.W. to E.N.E.

IV.—Messrs Richardson & Co.'s trial drive, right bank of Glentui, N. 48 E. to S. 48 W. 8ft. to 1in., horizontal and vertical.

REFERENCE TO NUMBERS ON THE FOREGOING SECTIONS.

1. Conglomerates and shales; coarse flaggy limestones.
2. Cherts near Diabasic beds.
3. Limestones.
4. Diabasic beds.
5. Sandstones, slates, and shales.
6. Greensands.
7. Quartzose sands, white, becoming ferruginous and glauconitic.
8. Shales with carbonaceous markings, and nests and streaks of coal.
9. Limestone, fossiliferous; position obscure.
10. Dolerite tufa.
11. Dolerite, older (like Hill's Drive).
12. Dolerite, Anamesite (like Harper's Hill).
13. Post-pliocene alluvium.


I
II
III
IV

REPORTS ON THE GEOLOGY OF SOUTHLAND.

BY CAPTAIN F. W. HUTTON, F.G.S.

Instructions to Captain Hutton by Dr. Hector.

22nd December, 1871.

I HAVE the honor to request that you will devote the next four months to the geological survey of that portion of the southern district of the Otago Province which extends from the Takitimu Mountains on the west, to the coast between the Mataura and Molyneux Rivers, and including the Wairaki and Taungatura Downs, the Hokanui Hills, and the Kaituka Ranges.

The special object of your survey will be to ascertain the extent and value of the coal seams which occur in the district, but for this purpose it will be necessary for you to examine the general structure of the district on several lines of section.

The lines which I recommend from my own knowledge of the district are marked on the attached plans.

Section I.—In a north and south direction up the valley of the Otapiri Creek is the first to which you should direct your attention, as there you will find the lower formations well displayed.

Section II.—North-east from the Takitimus, the Mount Hamilton district will give you a greater expansion of the middle part of the series.

Section III. is the section from the Takitimus south to the Morely Creek district, and on to the Yellow Bluff, on which line you will find the older and newer formations best developed.

Section IV. will intersect or approach several valuable seams of brown coal at the eastern extremity of the Hokanui. In the district east of the Mataura you will find very good sections on the lines marked, avoiding the heavy bush.

The coast section can only be reached by land as far north as Waikawa, and again at Catlin River and the Nuggets.

The following is a list of the localities where fossils have been gathered:—

Section I.—*Forest Hill Limestone*, with marine fossils; in this limestone are caves, with fine Moa bone deposits, which I should like you to examine if you have an opportunity.

Otapiri River, at *a*.—Astarte sandstone above the *pecopteris* beds at *a'* which have been explored by a drive from a bush gully; *b*, a low cliff of dark sandstone, in which I got *glossopteris*; *c*, *d*, *e*, (Kahiku series) are the calciferous shales, with wide winged *spirifer*, &c., under the conglomerates, which form the base of the Mataura series.

Section II.—Fossil plants occur in the Mount Hamilton sandstones, followed by *septaria* clays, also with fossils. I think the supposed coal at Coal Hill must be serpentine, but I have never been there.

Section III.—Older part of the Mataura series, with fossils *a*, *b*, *c*, also the brown coal with fossils at *d*, followed by green sands, marls, and limestones, all fossiliferous.

Mataura Falls.—Sandstones and shales, with fossil plants.

Waikawa.—Fossil plants at the localities marked on the plan.

Tautuku, on the coast.—Green sandstones, with plants and *ammonites.*

Catlin River.—Fossils at places marked on plan.

Shaw's, or Roaring Bay, and the Nuggets.—Fossils in limestone and indurated sandstone.

Kahiku Gorge.—Fossil shells.

Popotuna Gorge.—Fossil shells and plants.

Waipahi Creek.—Fossil shells.

The localities where coal seams are worked, or have been looked for, are—Mount Hamilton, irregular seams of good quality; Otapiri Creek, irregular seams, also brown coal nearer Forest Hill. The neighbourhood of this coal to the Winton railway station makes it desirable that you should report on the best place where a supply could be obtained for the use of the locomotives.

Morely Creek.—A good seam of brown coal, much of it burnt out however. On the Mataura River, from the falls up to M'Nab's, there are several seams of brown coal exposed, also at Hill's station and the Hokanuis. Below the falls a thick bed of lignite is worked.

Waikawa Harbour.—Several thin seams, as marked on the plan; the coal is good, but the seams are thin and irregular so far as yet explored.

If you should think it necessary to assist your investigations by "boring" in any part of the above district, you will inform me on the subject at as early a date as possible.

REPORT ON THE COAL DEPOSITS BY CAPTAIN HUTTON.

6th March, 1872.

I HAVE the honor to report that I was engaged from the 4th January until the 21st February last in examining the coal deposits of the Southland district, between the Mataura and Waiau Rivers, and the following is the result of my examination. The geology of the district will form the subject of a separate memoir.

The coal fields of this district may be divided into four areas, viz:—

1. The Hokanui district.
2. The Mount Hamilton district.
3. The Wairaki district.
4. The Orepuke district.

Of these, the two first contain seams of black bituminous coal, the two latter brown cannel or pitch coal. Extensive deposits of lignite, sometimes of very good quality, are also found in the valley of the Mataura, at Orepuke and near Invercargill, but as these can never have more than a local value, I shall make no further mention of them in this report.

1.—THE HOKANUI DISTRICT.

This district includes the whole of the Hokanui hills with the exception of the northern corner. The rocks are green sandstones, shales, grits, and conglomerates, which dip at angles never exceeding 20°, in various directions. The same formation extends under the plain between the Hokanuis and the sea, but it is here covered by a thick deposit of alluvial gravels containing beds of lignite.

At present coal has only been found in a few localities on the seaward slope of the Hokanuis, and even here only in seams too thin to be worked with advantage.

Up a small creek flowing into the Otapiri three thin seams of coal have been discovered, none of them, however, exceeding six inches in thickness. Higher up, I am informed by Mr. J. R. Thompson, a seam of carbonaceous shale, about four feet thick, exists, but without any good coal in it. This, probably, is the carbonaceous shale referred to in the Colonial Museum and Laboratory Report, 1868, p. 18. West of the Makarewa, coal has been found in several localities near Mr. Anderson's farm, but, also, it does not exceed a foot in thickness. This coal is black, and does not fall to pieces on exposure to the weather. It has not yet been analysed, but will no doubt prove of superior

quality, and if it can be obtained in a seam of not less than three feet in thickness, would be of considerable value.

It is, I find, a commonly received opinion that those portions of the formation that occupy the flat land below the gravels which form the plains between the Hokanuis and the sea, would not be so much disturbed as those portions that form the hills, and therefore that if coal could be found in the flats, by boring through the gravels, it would be much more advantageously placed for working; the supposition being that the hills are owing to an uplifting of the strata in those localities, while in the plains they have remained undisturbed.

This, however, is quite a mistake, as the whole of the formation has undergone the same amount of disturbance, and the hills are of that class sometimes called "hills of denudation," that is to say, that they are higher than the plains simply because where the plains now exist the rocks have all been washed away down to that level. If, therefore, a seam of coal was found below the plains there is no reason to suppose that it would be less disturbed than if it was in the hills, and a mine situated in the plains would entail great expense in pumping and lifting machinery, while one situated in the hills could probably be worked level free.

The plains, also, could only be explored by boring, which would be a very expensive operation, especially as the bore would have first to penetrate through a considerable thickness of loose gravel, in which the rods would be liable to stick fast, and would then have to be continued down through hard sandstone.

The hills, on the contrary, can be easily explored in the gullies, and a much greater extent of the formation, both horizontally and vertically, can be examined than by boring. As, therefore, there is as yet no evidence for supposing that a coal seam, thick enough to work, underlies the plains, it would, in my opinion, be only throwing money away to attempt exploration by boring; and instead, in order to encourage the prospecting of the hills, I should recommend that a reward be offered for the discovery in the Hokanui hills of a coal seam sufficiently thick to pay for working. This might, perhaps, be defined as a seam having a total thickness of not less than four feet of good coal, within a vertical depth of not more than six feet.

The same formation as that in which the coal is found in the Hokanuis, extends also across the Mataura river nearly as far as the Clutha, and from the sea nearly as far as the Kahiku mountains. Thin seams of coal have also been found in several places in this district, as

Waikawa, Toi-tois, Islay, Wyndham, &c. At Toi-tois, near the mouth of the Mataura, Mr. Brunton has explored some outcrops of coal by drives and a shaft. The following is the section of this locality:—

Conglomerate Green sandstones	...	...	...	200+
Fire clay	...	...	about	6.0
Coal, with shale partings		...	...	1.6
Dark grey shale	...	...	about	40.0
Coal (7 thin seams with shale)		...	...	6.0
Green sandstone	...	...	about	20.0
Conglomerate	...	...	...	15+

The whole dip 6° N.N.E.

The coal from Waikawa has been analysed, and the analyses are published in the Appendix to the Jurors Reports and Awards of the New Zealand Exhibition, 1865, p. 441, in Dr. Hector's First General Report on the Coal Deposits of New Zealand, p. 33, and the Third Annual Report on the Colonial Museum and Laboratory, p. 20. Other information can also be obtained from these publications.

The remarks that I have already made about prospecting the Hokanui Hills for coal, are equally applicable to the country about Waikawa, and I would therefore recommend that a reward be offered for the discovery of a payable seam in this district also.

2.—Mount Hamilton District.

This district is confined to a small portion of Mount Hamilton, which forms the N.E. end of the Takitimu mountains. The coal seams are thin and of very limited extent. The thickest seam that I could find was only ten inches of good coal, with shales above and below it, the whole overlaid by yellow sandstones, dipping 30° W.N.W. More to the west a few very thin seams of coal are seen interbedded with the yellow sandstones, which dip in this place 25° S.E.

The height of this coal field is 2,500 feet above the level of the flats at the base of the mountain, or about 3,300 feet above the sea. The position, therefore, as well as the thinness of the seams, and the limited area of the field, puts the practicability of working it quite out of the question. The coal, however, is black, bituminous, and of excellent quality.

3.—Wairaki District.

This district skirts along the southern base of the Takitimu Mountains and Wairaki Hills, from Taylor's Creek, on the west, as

far as the alluvial plain of the Jacob's River on the east, a distance of about eighteen miles. Near the Jacob's River it has a breadth, north and south, of about three miles, which gradually diminishes westward, thus forming a triangle, the apex of which is at Taylor's Creek, and the base at the southern spur from Mount Beaumont, called the Night Cap. This will give an area of about twenty-one square miles.

The coal in this district is quite similar in appearance to that worked in the Waikato, and is what is generally called "Brown Coal." As, however, this name, has been often employed for compact varieties of lignite, it would, I think, be preferable to use the name "Pitch Coal" for this class of coal, which may be distinguished from the lignites by never containing any trace of wood-like structure, by its pitch black color, and by its waxy lustre. This is the name used by Dr. Percy,* who considers it as the best variety of brown coal or lignite.

This coal, although inferior in heating power to the true black coals, will be found very useful for all household purposes, as well as for stationary engines. It is largely used by the steamers on the Waikato River with satisfactory results, and I have no doubt but that it would answer for locomotives also.

Analyses of this coal from Morely Creek will be found in the Appendix to the Jurors' Reports and Awards, N.Z. Exhibition, 1865, p. 441, No. 11, and also in the Third Annual Report of the Colonial Museum and Laboratory, p. 20, where the analyses from Taylor's Creek, Reinecker's run, Howell and Stevens' run, Holt's run, and probably Aparima, are all from this district. At Taylor's Creek a section is opened just on the edge of the basin, and a seam of coal five feet thick is seen to rest on the edges of slates and sandstones. The coal is here covered with shales and micaceous sandstone, the whole dipping 20° S.W. Following down the creek more black shales are seen to overlie the micaceous sandstone. These probably indicate the presence of a second seam of coal, but the section stops suddenly.

As the section here is evidently quite on the edge of the basin, the seam of coal may get thicker in a south-westerly direction.

At Linton, two seams are distinctly seen, dipping 25° S.S.W., but the thickness of neither of these has been ascertained. In a cliff on the right bank of the Morely Creek, the following section is displayed:—

* Metallurgy, p. 85.

Yellow sandstone	20+
Blue Marl	20
Coal	3
Shale	1
Coal	2
Shale	12
Coal	2
Shale	10+
	70+

The whole dipping 25 ° W. by S. Higher up the Morely Creek, at Messrs. Reinecker's and Hunter's Station, the coal has been opened up in several places. The thickness, as ascertained close to the home station, was ten feet, and the dip 25 ° S.W.

The nearest place to the railway at which the coal has been found as yet is on the west side of the Night Cap Hills; it has not however been opened up sufficiently to ascertain either its dip or thickness.

A tolerably approximate estimate of the quantity of coal in this field cannot be given without a great deal more data to go upon, on account of the variation in the dip and thickness of the seams; and the expense attending the obtaining of such data would be far more than it would be worth, for it can already be safely stated that the coal exists in sufficient quantity to justify a large mine being opened in it.

The nearest place to Winton, at which this coal is likely to be found, is in the eastern slopes of the Night Cap Hills, from which point a railway of eighteen miles in length would reach Winton, over quite level ground. The way to proceed in order to find the coal on the eastern slopes of these hills is, first to open out the known outcrop on the western side and obtain as accurately as possible the direction of the strike of the seam—this is of course at right angles to the dip —a line should then be run with a level over the hills in the direction of the strike until the same level is reached on the eastern side as the known outcrop on the western side; a few feet above this point a bore should be put down, and, if it is successful in striking the coal, the seam may be either opened up at that place or two other bores be put down in order to get the dip of the seam. When the dip of the seam is ascertained at that point, but little difficulty will be experienced in hitting off the position of the seam at the level of the plains of the

Jacob's River, and a drive put in there will be the best position for opening a mine.

4.—Orepuke District.

In this district the coal is situated at about a height of from 150 to 200 feet above the sea, and about five miles rom the beach. It occupies a portion of the Valley of the Waimeamea River, and is about three miles in length and one in breadth.

The coal is exactly similar in appearance and quality to that of the Wairaki district just described. At present it is only exposed in water races, some of which have fallen in, and in no place was I able to measure its thickness. It is, however, evident that this is considerable, and, according to the miners, from ten to fifteen feet.

It is covered with dark very tough shales, and the floor is composed of chocolate colored shales. The upper part of the formation is soft green sandstone; the dip is about 12° S.S.W.

This coal is of good quality, but not superior to that from the Wairaki district, while it is neither so accessible in position, nor so extensive in quantity. As the country in which it occurs is well covered with bush it is not likely that this coal will be used, even for local purposes, for some time.

It appears to me, therefore, that the only coal field of any commercial value at present known in Southland is in the Wairaki district, and I think that this could be at once opened up with great advantage to the country.

ON THE GEOLOGY OF THE DISTRICT OF SOUTHLAND, IN THE PROVINCE OF OTAGO, BY CAPT. F. W. HUTTON, F.G.S., C.M.Z.S.

10th May, 1872.

Narrative of Exploration.

I left Dunedin on the 4th of last January by coach, and went by Popotunoa and the Mataura Falls to Invercargill, which I reached on the 5th. On the 8th, I went by Winton to Mr. Webster's station at Benmore, on the Hokanuis, where I staid until the 12th, examining the neighbouring country. I then rode back to Invercargill, and went from there, *viâ* the Seaward Downs and Menzies' Ford, to the Hon. Mr. Menzies' station, on the Mataura, on the 15th. The next day I went down the Mataura to Mr. Brunton's station at Toi-tois, and on the 17th returned to the Mataura Falls and examined the lignite

beds there. The next day I examined the eastern base of the Hokanuis, and crossing the Mataura at the Long Ford, went to Mr. M'Nab's station of Knapdale. There I examined the lignite beds and gold washings on his run. I then went, *viâ* the Pyramids and Mr. Bell's station on the Waimea Plains, to Mr. Dundas' station on the north of the Hokanuis. The next day I went *viâ* Mr. Cowan's station on the Hokanuis, across the Oreti River to the Hon. Mr. Holmes' station of Castle Rock. There I spent two days examining the Moonlight Ranges, and on the 23rd proceeded to Mr. Thornhill's station near Centre Hill. The next day I examined the Mount Hamilton coal-field, and then crossed the Mararoa to Mr. Clarke's station. On the 25th I went along the western base of the Takitimu Mountains to Mr. Dundas' station, near Manipouri Lake, and down the Waiau to Black Rock. The next day I examined the brown coal in Taylor's Creek, and went by the Upper Wairaki to Linton station. Next day I examined Linton Creek, and then went up Morely Creek to Messrs. Reinecker's and Hunter's station. I remained here until the 30th examining the neighbourhood, when I went down the Jacob's River to Messrs. Gillow and Sutton's farm on the Narrows, near Riverton. Next day I crossed over the base of the Longwood Ranges to Orepuke, where I remained one day examining the coal and gold-fields, and on the 2nd February returned to Mr. Gillow's. Next day I went to Forest Hill, and on the following to the Otapiri Creek in the Hokanuis. I then went on to the Makarewa Creek. The next day I examined the coal beds in the neighbourhood, and returned to Winton, and on the 6th went to Invercargill. On the 7th I started for Lake Wakatipu, and reached Queenstown on the 8th; on the 9th, I went up to the head of Lake Wakatipu, and returned to Queenstown on the 10th. I remained here until the 12th, when I went to Athol, and on the next day to Winton, and reached Invercargill again on the 14th. I remained there until February 17th, when I went to the Bluff, and there staid until the 21st, when I embarked in the Alhambra for Wellington.

Description of District.

The district that I examined is bounded on the west by the River Waiau, from its mouth to Manipouri Lake; on the east by the River Mataura, from its mouth to Lake Wakatipu; and on the north by a line from Manipouri to Kingston, on Lake Wakatipu. It may be described as consisting of a series of mountain ranges, separated from

each other by flat-bottomed valleys, which gradually converge to form the broad alluvial plains of Southland, extending from the Hokanui and Moonlight ranges to the sea.

Geological Structure.

The geological structure is simple but highly interesting, as it presents us with an almost complete series of formations from the palæozoic schists up to the tertiary limestones and marls, thus marking out the main features of the geology of New Zealand, and supplying us with a standard to which we may refer formations, which in other parts of the islands are often found isolated.

The whole of the district is included in an inclined trough of palæozoic and secondary rocks, the major axis of which lies in a south-east and north-west direction, rising towards the north-west, so that the palæozoic rocks are here thrown up and close this end of the trough, while the south-east end, towards the Mataura, is open. The minor axis also inclines upwards to the north-east, so that this side is raised higher than the south-west side. The belt of palæozoic rocks that forms the rim of this trough runs from the Pyramids and Umbrella Mountains on the north-east, through the Dome and Eyre Mountains on the north, round by the Takitimu and Longwood Mountains on the west, to the Bluff Hill on the south-west. In its folds are enclosed large masses of secondary rocks, which form the Wairaki, Moonlight, and Hokanui Ranges, and which extend across the Mataura to Waikawa and Port Molyneux.

The south-west edge of this trough has been broken down in several places, and tertiary rocks have been deposited indifferently on both the inside and the outside, and overlapping its edge. These have also, in their turn, been largely removed by denudation, and replaced by immense deposits of gravel and silt, which belong to the quaternary epoch.

Section 1, taken along the major axis of the trough, shews the secondary rocks, (*c* and *d*), resting on the palæozoic rocks (*b*), forming the upper rim at the Takitimu mountains, while the tertiary rocks (*g*) are seen both outside the trough on the north-west and inside at Castle Rock. It also shews the older rocks coming up one under the other as we advance to the north-west, owing to the upward rise of the major axis of the trough in that direction.

Section 2, taken across the major axis, also shews the tertiary rocks (*f* and *g*) both inside the trough and outside, at Orepuke.

Section 3, taken along the minor axis of the trough, shews the older secondary rocks (*c*) coming up between the Otapiri and Waimea on the north-east margin of the trough, while towards the south-west they do not rise above the sea level owing to the downward inclination in this direction of the minor axis.

From these considerations it appears that the chief movements which gave rise to the present internal, or geological structure of this portion of New Zealand, took place after the secondary rocks had been formed, and before the tertiary rocks had been deposited on their upturned and denuded edges; thus indicating a great break in the sequence at this point.

The older palæozoic and secondary rocks are most disturbed and bent in the west and north-west portions of the trough, while towards the south-east they get more horizontal. The tertiary rocks, on the contrary, although principally occurring on the west and north-west side of the trough, are, on the whole, nearly horizontal, (their dips being local, in various directions, and quickly changing), but rising gradually towards the north, and circling round the bases of the older palæozoic and secondary mountains; thus shewing that since their deposition no great *internal* changes in the position of the rock masses have taken place in this part of New Zealand, although vast *external* changes, caused by denudation, have torn them into fragments.

The following is a synopsis of the formations into which I propose to divide the rocks, premising that, until the large collection of fossils which has now been made from all parts of New Zealand has been examined and described, it will be impossible to feel much confidence in the ages assigned to them.

Quaternary	(*h*)	Alluvial.
Tertiary	(*g*)	Middle and Lower
	(*f*)	Brown coal formation
Secondary	(*e*)	Upper
	(*d*)	Middle
	(*c*)	Lower
Palæozoic	(*b*)	Upper
	(*a*)	Middle

Each of these formations rests unconformably on the one below it. I have seen no volcanic rocks in the district.

Middle Palæozoic Formation.

A small portion only of this formation, extending from near Athol to Lake Wakatipu, comes into the district under review. It consists

of mica-schist, clay-slate with a satiny lustre owing to innumerable minute plates of mica, often waved or corrugated, and dark green chloritic mica-schist with layers of white quartz.

The strike of the foliation plane is north-west and south-east, and the dip at Kingston 15° S.W. As the changes in the lithological characters of these rocks take place in a direction at right angles to the plane of foliation, it follows that the foliation coincides with the original bedding. This, also, might be inferred from the small angle of inclination to the horizon that these schists have over a large extent of country (Hector on the Geology of Otago, Quar. Jour. Geo. Soc. 1864, p. 126); for if the foliation had taken place along planes of cleavage it would have had the high angles of inclination which usually belong to that structure, caused by the planes of cleavage having been formed at right angles to pressure laterally applied.

The great uniformity of the dip, and the absence of contortions in this district, also proves that these rocks have never undergone any considerable lateral pressure, and therefore that cleavage on an extensive scale cannot be expected to occur in the neighbourhood.

This is the chief auriferous formation of Otago (Hector Mining in New Zealand, Trans. N.Z. Inst. II., 346), its age is, at present, quite uncertain, farther than that it underlies the next formation, which must be considered as palæozoic; I have, therefore, here called it "Middle Palæozoic," reserving the name "Lower Palæozoic" for the "Gneiss-granite" formation of Dr. Hector (Quar. Jour. Geo. Soc. 1864, p. 128, *k*), on the south-west coast, which I have not as yet seen.

Upper Palæozoic Formation.

(*Te Anau series of Dr. Hector.*)

The distribution of these rocks through the district, and the principal localities in which they are found, have already been mentioned when speaking of the general geological structure of the country (*vide* ante p. 98). They consist of soft bluish-grey phyllite, dark green and grey slates, sandstones, and a compact semi-crystalline green rock, sometimes passing into breccia, with the composition of diorite or green-stone (Diorite Sandstone of Dr. Hector). This rock appears to be very similar to the "Schalstein" of Nassau, mentioned by Messrs. Sedgwick and Murchison (Trans. Geo. Soc. 2nd Series VI p. 249), but it seldom has the platey or schistose structure there described. Closely allied rocks, called "Felspathic Ash," by Professor Ramsay (Memoirs of the Geo. Survey of Great Britain III, p. 25, 109, &c.),

occur abundantly in the Cambrian and Lower Silurian formations of North Wales. All three of these authors agree in considering that these rocks have originated in contemporaneous submarine volcanic outbursts, and owe their present appearance to subsequent metamorphic action.

Heavy masses of conglomerate are also found on the top of Coal Hill, on the northern flanks of Mount Hamilton and the Takitimu Mountains, and at Black Rock on the Waiau, but I was not able to satisfy myself as to the age of these deposits, and it is possible that they may belong to the Lower, or even to the Upper Secondary formations

I have not been able to examine a junction between this formation and the last, and therefore cannot say whether the metamorphism of the mica-schist formation is or is not clearly separated from the sub-metamorphism of these rocks, but, judging from the greater amount of metamorphic action seen about Athol, I am inclined to think that one will be found to pass gradually into the other.

Near Athol this formation consists principally of bluish-gray phyllite, striking N.N.E. and dipping 45° E.S.E., but west of Athol the dip alters to the W.N.W. The strike of the middle palæozoic rocks in the neighbourhood is N.W. and S.E., thus showing a marked unconformity between the two formations. At Coal Hill (a south-west spur from the Eyre Mountains), slates and fine grained sandstones are seen dipping 75° E. by N., while at Centre Hill, the same rocks dip 50° W. by S., and more to the south, in Mount Hamilton 65° to 40° E. The Takitimu Mountains are chiefly composed of phyllite, like that seen at Athol, and with the same strike, viz., N.N.E., the beds dipping to the E.S.E. and W.N.W. alternately. At the Narrows, near Riverton, nearly vertical beds of sandstone are seen striking S.E. and N.W., while at the Bluff the strike of the slates is E.S.E. and W.N.W., the dip being from 75° N.N.E. to vertical. At the Pyramids the sections were too bad, and the bedding too much obliterated, to enable me to get the strike of the argillites and sandstones that compose those hills. By the term "argillite," I mean a rock formed from thick beds of clay that have undergone a sufficient amount of metamorphism to obliterate the lamination, while it has not been sufficient to induce any signs of foliation, thus distinguishing it from "phyllite," in which incipient foliation is distinguishable. Argillite is always much jointed in several directions, so as to break into irregular rhombohedrons. This structure is probably caused by

shrinkage during desiccation, and proves therefore that while the metamorphic action was in progress the rocks were not subjected to any violent lateral pressure.

Dykes of diorite are associated with these rocks at the Bluff, and also in the Longwood and Takitimu Mountains. This diorite is composed of white felspar and crystals of black hornblende, often at the Bluff passing into an almost pure hornblende-rock. Sometimes the rock is of a green color, caused by the dissemination of minute particles of hornblende through the mass, but when exposed to the weather these minute particles soon disappear from the surface, leaving the larger crystals studding the white felspar base with black spots. At the Bluff Hill a broad diorite dyke runs nearly parallel with the bedding of the slates, and the line of junction between the two rocks is very complicated, veins of diorite, isolated from the main mass, appearing among the stratified rocks parallel with the bedding, and looking as if the diorite was here a product of metamorphism, and that the argillaceous beds had been changed into diorite, while the more arenaceous ones had resisted the action. These appearances however are, I am inclined to think, fallacious, and that the diorite is in reality intrusive, for in Kolag's Bay, near Riverton, a dyke is seen running out to sea in a southerly direction, while the strike of the sedimentary rocks is S.E. and N.W. At the Great Barrier Island also dykes of diorite, resembling this in every respect, are clearly seen cutting through the slate rocks. (Geo. of Great Barrier, Geo. Reports, 1868-69, p. 3).

Fragments of a compact and rather hard variety of serpentine, of a dark green or black color are found in the bed of the stream south of Coal Hill. I did not see it *in situ*, but suppose that it occurs as a dyke. In Taylor's Creek, which runs from the southern slopes of the Takitimu Mountains, I also found pieces of jasperoid slate, like that found at Waiheki, Kawau, and other places in the Province of Auckland.

Gold in small quantities is found throughout this formation, but the Longwood Range is the only place in which it occurs to any considerable extent. The gold of the Orepuke district must have come out of these rocks, as it is found up the valley of the Waimeamea, a small river rising in the Longwood Range. I detected fossils in this formation in two localities only, viz., Centre Hill near Mount Hamilton, and Coal Hill, a spur from the Eyre Mountains. In these places the fossils, although abundant, consisted of one species only, probably a

Foraminifer. This animal grew in parallel, or concentric layers, with a fibrous structure vertical to the laminæ, and formed large sessile patches of irregular but often discoidal shape. It has much the appearance of *Stromatopora*, which is supposed to be a coral, but the laminæ are 0.04 of an inch in thickness. I am inclined to think that it will prove to be a reef-building *Foraminifer* allied to *Eozoon*.

With such scanty materials it is of course impossible to refer these rocks to any particular formation of the palæozoic period, but that they belong to that period we may safely infer from their underlying the formation next to be described, which contains fossils specially characteristic of the triassic rocks in Europe. I am, however, of opinion that more than one formation is included in what I have here termed Upper Palæozoic, but in my rapid survey I saw nothing that would enable me to divide it into two.

Lower Secondary Formation.

(*Kahikau series of Dr. Hector.*)

The principal mass of this formation is found in the Wairaki and Moonlight Hills, but a considerable patch occurs in the north and north-west portion of the Hokanuis; Twinlaw Hill, also, between the Longwood Range and the Wairaki Hills appears to be an outlier.

The rocks composing this formation are blue, more or less arenaceous slates, green sandstones, grits, and sub-angular conglomerates, with pebbles of slate and sandstone, but none of any igneous rocks. Green felspathic-slates (diorite sandstone), also occur, but not so commonly as in the last formation. The average strike is about north-west and south-east, varying a little to either side on account of the anticlinal and synclinal axes dipping downwards to the south-east. The strike of the palæozoic rocks in the Takitimu Mountains, on which these lower secondary rocks abut, is north and south, thus shewing an evident unconformity, but I have not examined the line of junction between the two formations in the Wairaki Hills.

At Castle Rock Station, on the north side of the Moonlight range, the dip is 20° S.W. while further south, near Dipton, it is 30° S.S.W. On the opposite side of the Oreti River, above Benmore, these rocks dip 20° S.S.W.; and on the north-west slopes of the Hokanuis, in the bed of the Waimea stream, 60° N.E. by E., while at the head of the Otapiri they are vertical, and strike north-east and south-west. On the southern part of the Wairaki Hills, near the head of the Morely Creek, the dip is 20° N.E., and at the gorge, where the creek enters the plain, 15° S.W.

These rocks are much less metamorphosed than those last described, and the fossils are much more abundant. On the eastern slope of the Moonlight Range, on the spur of a hill about four miles north of Dipton Station, beds composed almost entirely of *Monotis salinaria* var. *richmondiana* Zitt. and *Halobia lomelli* Wissm. occur, and at this spot I also obtained a longitudinally ribbed *Mytilus*, and an imperfect cast of a species of *Perna*. I was also informed that the same fossiliferous masses occur on the hills to the north-west of Castle Rock, this place being in a W.N.W. direction, or on the strike of the beds, from the one I visited. On the opposite side of the Oreti River, at a place called Cowan's Wash, on the western slope of the Hokanuis, I obtained *Monotis*, *Halobia*, a large ribbed species of *Pecten*, and many plant remains; and at Morely Creek, on the south side of the Wairaki Hills, I got *Halobia*, and casts of *Isocardia*, *Trochus*, &c.

These fossils show that the rocks are the same as the sandstones of Richmond, near Nelson, and they prove without doubt the Triassic age of the deposits, thus giving us an admirable horizon for estimating the probable ages of the other formations both above and below it.

Middle Secondary Formation.

(*Mataura series of Dr. Hector.*)

This formation forms the whole of the Hokanui Hills with the exception of the northern corner. It also appears to form an outlier on the south-east corner of the Moonlight Range, and is seen in the beds of the creeks in the Seaward Downs, below the alluvial formation of the Southland Plains. Eastward of the Mataura it covers an extensive area of country. It is composed of blue slates, shales, slaty sandstone, green and brown sandstones, grits, and conglomerates. The conglomerates contain pebbles not only of slate and quartz, but also of a pale purple porphyry, with crystals of white felspar, and of pink granite, thus proving that at some time previous to their deposition metamorphism of the older rocks had taken place on an extensive scale, and that denudation had proceeded so far as to lay bare the crystalline rocks.

At Bastion Hill, near Mr. Webster's station at Benmore, a splendid section of these rocks is obtained, and they are here seen to dip 10° S.E. by S., or nearly at right angles to the triassic beds at Cowan's Wash, which is in close proximity, thus proving a complete unconformity to exist between the two. Following this formation in a south-easterly direction it is seen, about the Makarewa Stream, to get

horizontal, and farther on in the same direction to have a W.N.W. and E.S.E. strike. At the eastern end of the Hokanuis the dip is 30° S.S.W., while at the Mataura Falls, a little more to the south, it is 3° N.N.E. On the left bank of the Mataura, about half way between the falls and the mouth, near the Hon. Mr. Menzies' station, the dip is 10° N.N.W., and at Toi-tois, near the mouth of the river, 6° N.N.E.

Several thin seams of coal have been found in this formation at Otapiri, Makarewa, and near the mouth of the Mataura, but none of sufficient thickness to warrant the opening up of a mine. This coal is black and bituminous, but, as might be expected in thin seams, it contains so much ash that it is hopeless to try to obtain the amount of water combined with it with sufficient accuracy to be of any use in a comparison with coals from other formations. From Bastion Hill I obtained a compressed *Pholadomya* about an inch in length, and three-fifths of an inch in height, concentrically furrowed, and finely radiately striated; and from the tributary of the Otapiri, in which coal has been found, but at a lower level than the coal, I obtained a species of *Astarte*, which I cannot distinguish from *A. wollumbillaensis*, Moore, (Quar. Jour. Geo. Soc. xxvi., p. 250, pl. xii., fig. 12). At the Otapiri, Seaward Downs, Mataura Falls, and other places abundance of ferns of the genera *Polypodium*, *Tæniopteris*, &c., are found, apparently identical with those from near Port Waikato, where they are associated with *Belemnites aucklandicus*, *Placunopsis striatula*, and *Aucella plicata*. I have therefore very little doubt but that these rocks are the equivalents of my Putataka series, in the North Island (Geology of the Lower Waikato, Wellington, 1867), which Dr. Zittel thinks are of Jurassic age, while Mr. C. Moore also is of opinion that the rocks from which *A. wollumbillaensis* comes probably belong to about the horizon of the Oxford clay (l.c., p. 239), which may be considered as the middle of the Jurassic formation.

Upper Secondary Formation.

This formation is at present only known in this district by a small patch of rocks near the summit of Mount Hamilton, at an elevation of 2500 feet above the level of the alluvial plain of the Oreti, or probably some 3,300 feet above the sea (sec. 5). It is composed of yellow sandstone with thin seams of coal, underlaid by shales with several seams of good black coal, the uppermost of which is ten inches in thickness. Below this comes a conglomerate which rests unconformably on upper palæozoic rocks. The upper sandstone is fine

grained, but in it I noticed a large angular boulder of dark grey sandstone, measuring eight feet by three in the exposed face; no other pebbles of any kind were near it, and it rested on the top of a thin coal seam. I presume that there can be no doubt but that this boulder has been floated among the roots of a tree to its present position, and that, therefore, the coal beds are formed principally from drift wood.

This patch of coal formation is in a synclinal arrangement, the axis of which inclines downwards to the S.W. by S., the western portion dipping 25° S.E., and the eastern 30° W.N.W., while the dip of the underlying rocks is 40° to 60° E.

The sandstones above the coal contain numerous impressions of dicotyledonous leaves, all of which are quite distinct from those described by Professor Unger as coming from Drury (Voy. Novara Geology II). There is no direct evidence in this district to shew what relation these beds bear to the formation just described, but they must have overlapped them considerably. The leaves of dicotyledons which they contain, prove that they are probably not much older than the upper cretaceous, while, on the other hand, there is, as I have already mentioned, (ante, p. 99) strong evidence to shew that the break between them and the next formation is very large; and, as that can hardly be considered younger than the middle or upper Eocene, I am inclined to think that these Mount Hamilton beds will prove to be of upper cretaceous age.

From their stratigraphical position, we must infer that these rocks have partaken in the latest disturbances on an extensive scale, which have caused the present internal structure of the New Zealand Alps, and in this, as well as in containing leaves of dicotyledonous plants, these beds strongly remind me of the coal formation of the Upper Aorere, and Collingwood, which is part of the Pakawau field, which Dr. Hochstetter (New Zealand, p. 87), Dr. Hector (Progress Report 1866-67, p. 18) and Dr. Haast (Geological Reports, 1870-71, p. 7) all agree in considering as the same formation as that of the Grey and Buller coal-fields.

The coal, also, from Mount Hamilton is quite of the same class as that from the Grey and Buller, as will be seen from the following table, which shows the ratio of the Carbon and Hydro-Carbons in these coals to the water:—

	Water.	Carbon.	Hydro-Carbons.
Mount Hamilton ...	1	30.6	23.7
Grey and Buller ...	1	30.2	18.2

And although I think that the thickness of the deposits above the coal, and the amount of disturbance they have undergone, have more to do with its quality than mere age, still as both thickness of superior deposits, and amount of disturbance, depend to a certain extent upon age, a similar quality of coal in deposits situated within the same area of disturbance, as is the case here, must be taken as of considerable weight in determining the age of the beds.

The following analyses of coal from Mount Hamilton have been made by Mr. W. Skey.

	a.	*b.*
Water	1.68	1.58
Fixed Carbon	49.08	49.01
Hydro-Carbon	39.44	39.61
Ash	9.80	9.80
	100.00	99.97

Brown Coal Formation.

The main body of this formation is found skirting round the south-west and west bases of the Wairaki Hills and Takitimu Mountains, but another small patch is also found on the south-west side of the Longwood Range, at Orepuke, in the valley of the Waimeamea. It never rises to great altitudes, but occupies portions of old valleys scooped out of secondary and palæozoic rocks. As this is the oldest formation that is found occupying parts of existing main valleys, it gives us an approximate date for their erosion, and proves that since the deposition of the upper secondary rocks, elevation and denudation on equally vast scales had taken place; thus indicating an immense lapse of time quite unrepresented in our formations.

At Taylor's Creek, the rocks consist of grey micaceous sandstone; shaly brown coal, five feet thick; and brown and chocolate shales, dipping 20° S.W., and resting on the denuded surface of upper palæozoic sandstones. Sometimes shales with leaves intervene between the upper sandstone and the coal, but sometimes the sandstone rests directly on the coal. It often contains large rounded boulders of the palæozoic rocks.

At Linton home station, two distinct seams can be made out, but the thickness of neither is known. The lower seam is overlaid by micaceous sandstone, like that at Taylor's Creek, and the upper one is in the sandstone. This latter has a very uneven floor. The dip here is 25° S.S.W.

In the lower part of Morely Creek the following section can be seen:—

Grey and yellow sandstone		?	
Blue Marlstone	...	20 feet,	leaves and *Unio*
Brown Coal	...	6 „	
Shale ...	...	12 „	leaves
Brown Coal	...	2 „	
Shale ...	...	? „	leaves

The dip is 25° W. by S.

Higher up the same creek, at Messrs. Reinecker and Hunter's home station, the coal is again found in several places, covered by the same micaceous sandstone as at Taylor's Creek and Linton. At the time of my visit there was no section open in which the thickness of the seam could be measured, but Mr. Reinecker informed me that it was ten feet. I think, therefore, that there must be some mistake in the information supplied to Dr. Hector by Mr. Thompson that the coal seam was eighteen feet in thickness at this place (Third Annual Laboratory Report, 1868, p. 18), especially as Dr. Hector describes it as ten feet in his Progress Report, 1868-69, p. iv. The same coal has also been found in two localities lying south-west of a small hill called the Night Cap.

At Orepuke, the same brown coal forms a bed of about ten feet in thickness up the valley of the Waimeamea. It is here accompanied by tough dark shales, and dips 10° S.S.W. The shales accompanying these coal beds, and the sandstones up Linton Creek, contain leaves of dicotyledonous plants, as well as of a fern resembling in general form *Polypodium hochstetteri*, Unger, but which no doubt will prove to be different from it. At the section exposed on the banks of the lower Morely Creek I also found in abundance an oval, ventricose, slightly corrugated species of *Unio*, thus proving the formation to be of fresh water origin. The coal contains quantities of fossil resin (*Ambrite* of Haidinger), and is similar in quality to that now worked on the Lower Waikato, and in appearance it cannot be distinguished from it. The following table shows the ratio of the Carbon and Hydro-Carbons in these coals to the water:—

	Water.	Carbon.	Hydro-Carbons.
Morely Creek ...	1	2.5	2.22
Waikato	1	3.4	2.6

The formation also has the same stratigraphical relations as that of the Waikato and Drury coal-fields; both skirt round the base of palæozoi

hills, and both are overlaid by limestones of the same age, with a slight unconformity between the two formations (*vide* post, p. 110, and Trans. N.Z. Inst., III, p. 245, 246). I cannot therefore doubt but that they are of the same age, but I will postpone the remarks that I have to make as to what their age is until I have described the other tertiary formations.

For analyses of these coals see Laboratory Report, 1868, p. 20, and New Zealand Exhibition, Jurors Reports, Appendix, p. 441.

Middle and Lower Tertiary Formations.

These formations cover a considerable extent of country in the western parts of the district, extending from near the sea, on each side of the Longwood Range, up the valley of the Waiau to the Manipouri Lake and western side of the Takitimus, where they expand largely to the north and east, stretching from Te Anau Lake to the sources of the Oreti River.

Four outliers are also found in the central and eastern parts of the district. One, on the left bank of the lower Oreti, forms a long narrow strip of low hills, running in a N.N.W. direction from Forest Hill, near Winton, to Centre Bush Hill on the Oreti River. Another long patch occurs in the Waimea Plains, extending in a north-east and south-west direction between the Waimea River and the Mataura. This patch does not form hills, and cannot be distinguished in outline from the alluvial terraces of the plain. Two other small outliers are also found in the valleys of the Moonlight Ranges, one forming the picturesque Castle Rock, and the other a small hill north-east of Castle Rock.

These formations must, when viewed on a large scale, be considered as nearly horizontal, but rising slightly to the north. They, however, often dip in various directions for short distances; thus, at Castle Rock the dip is 10° N.N.W.; at Lime Hill, near Winton, 30° S.E.; at Forest Hill, and in the Waimea Plains, nearly horizontal, but inclining slightly to the south-west; while on the northern base of Centre Hill the dip is 10° to 40° N.W. The whole of these rocks, with the exception of the north-west corner from Black Rock to the head of the Oreti River, are composed either of shelly limestone or of calcareous sandstone, and contain the following fossils, viz.:—*Hemipatagus formosus*, *Waldheimia lenticularis*, *Terebratula gualteri*, *Pecten hochstetteri*, *Pecten polymorphoides*, and several other species at present undescribed, which are also found at Oamaru, in Otago, Weka Pass,

in Canterbury, Aotea and Raglan in Auckland, &c., and characterize our oldest tertiary marine beds.

In the north, near Lake Te Anau, the rocks are chiefly clays and marls, and I was shown by Mr. Clarke some fossils, collected by his shepherds in the Upokororo Creek, which must certainly be referred to our middle tertiary formation, among them being a strongly tuberculated *Struthiolaria*, and a large *Cucullæa*, similar to one found at Waikari, in Canterbury, and on the east coast of Wellington at the "Taipos." A patch of limestone containing the same *Cucullæa* is also found in the valley of Lake Wakatipu, at Moke Creek, about seven miles above Queenstown.

The tertiary rocks on the north-west side of Mount Hamilton and Centre Hill consist of blue fissile marls, with large flat calcareous concretions, and reddish-yellow sandstone. They contain a few fossils, but I could only find a small internally-ribbed *Pecten*, allied to *P. pleuronectes L.*, and an *Echinoderm* with large smooth spines. The *Pecten* resembles one figured by Zittel, from the Waitemata series in Auckland (Voy. Novara, Geology, II., pl. ix., fig. 1*b*.), but as a larger form of this, or a very similar species, is also found associated with fossils that characterize the Oamaru series, it must at present remain doubtful as to which of these formations it should be referred.

The limestone formation of the Lower Waiau and Jacob's River lies above the brown coal formation, but as Dr. Hector has pointed out (Progress Report, 1868-69, p. iv.) an alluvial plain prevents their junction being seen. However, near the mouths of the Waiau and Jacob's River the limestone formation is found at and below the sea level, while the brown coal formation at Orepuke, between the two, is at an elevation of 250 feet above the sea (Sec. VI.), and, as there are no signs of its occupying an anticlinal ridge, an unconformity must necessarily exist between the two. It is also to be expected that the abrupt passage from a fresh water lake deposit to one entirely marine would show some marks of unconformity. The brown coal formation also must either have thinned out to the east, or it must have been denuded from the base of the Hokanuis, and probably the Moonlight Ranges, before the deposition of the limestone, for the latter approaches at the Oreti River so close to the middle secondary formation, and the valley which it occupies is so shallow, as proved by the outcrop of the secondary rocks on the Seaward Downs, that there is no room for the brown coal series to come in between.

As the greater part of the fossils from this formation have not yet been examined, I am unable to state with any confidence its probable age. Dr. Mantell, in 1850, with the very imperfect evidence he then had, was of opinion that the Oamaru (Ototara) series was either of Upper Cretaceous or Eocene age (Quar. Jour. Geo. Soc. VI., p. 329). While Dr. Stacke, in 1864, from a study of the *Foraminifera* brought home by Dr. Hochstetter was inclined to place it in the Oligocene or Upper Eocene formation. The number of recent species is certainly very few, probably not more than seven per cent., so that it cannot well be younger than Upper Eocene, while, if I am right in regarding the Upper Secondary rocks as Upper Cretaceous, the long interval that elapsed between the two formations will throw these tertiary beds as far forwards at least as Lower Eocene. The brown coal formation we may therefore regard as Lower or Middle Eocene, and the limestone beds as Middle or Upper Eocene, while the *Cucullæa* beds of Te Anau Lake may be considered as Miocene.

Alluvial Formation.

This formation forms the wide plains from the sea to the Hokanui Mountains, and stretches inland, up the river valleys, as far as Lake Wakatipu, in places filling valleys through which no river now runs, such as that of the Waimea, which connects the basin of the Oreti with that of the Mataura.

The base of this formation near the mouth of the Oreti, at Invercargill, and up the valley of the Mataura from the falls as far as Longridge, is often formed by extensive deposits of lignite, sometimes thirty feet in thickness, often passing into brown coal. It may, however, generally be distinguished from the true brown, or pitch coal of Eocene age by its lighter color, and by the occasional presence of vegetable tissue. It also contains a resin similar to the Ambrite of the brown coal. This lignite is well developed a little below the Mataura Falls; near the eastern foot of the Hokanui Ranges; at Mr. M'Nab's, on the Mataura; and at Mr. Bell's, on the Waimea; but I have never heard of any having been found up the valley of the Oreti.

The remainder of the formation is almost entirely composed of wide-spread beds of coarse shingle, with occasional layers of silt, the whole generally capped with surface soil. The Seaward Plains as well as the river valleys are distinctly terraced, and the tops of the terraces as well as the bottoms of the valleys are remarkably flat and level.

No fossils have been found in this formation. I am, however, of opinion that it has, at least the seaward portion, been formed by the sea spreading out the detritus brought down by the rivers, while the lignite beds owe their origin to drift timber also brought down by the rivers, but at a time when the land was sinking, and before the shingle was spread over them, while the shingle deposits themselves indicate a period of elevation.

The following table, which is compiled from analyses made by Mr. W. Skey, shows the average composition of the different coals, omitting the ash :—

	Water.	Carbon.	Hydro-Carbons.
Quaternary Lignite ...	20.2	42.5	37.3
Tertiary Brown Coal ...	15.2	49.9	34.9
Secondary Bituminous Coal	2.8	62.6	34.6

REPORTS ON THE NORTHERN COAL FIELDS.

BY CAPTAIN F. W. HUTTON, F.G.S.

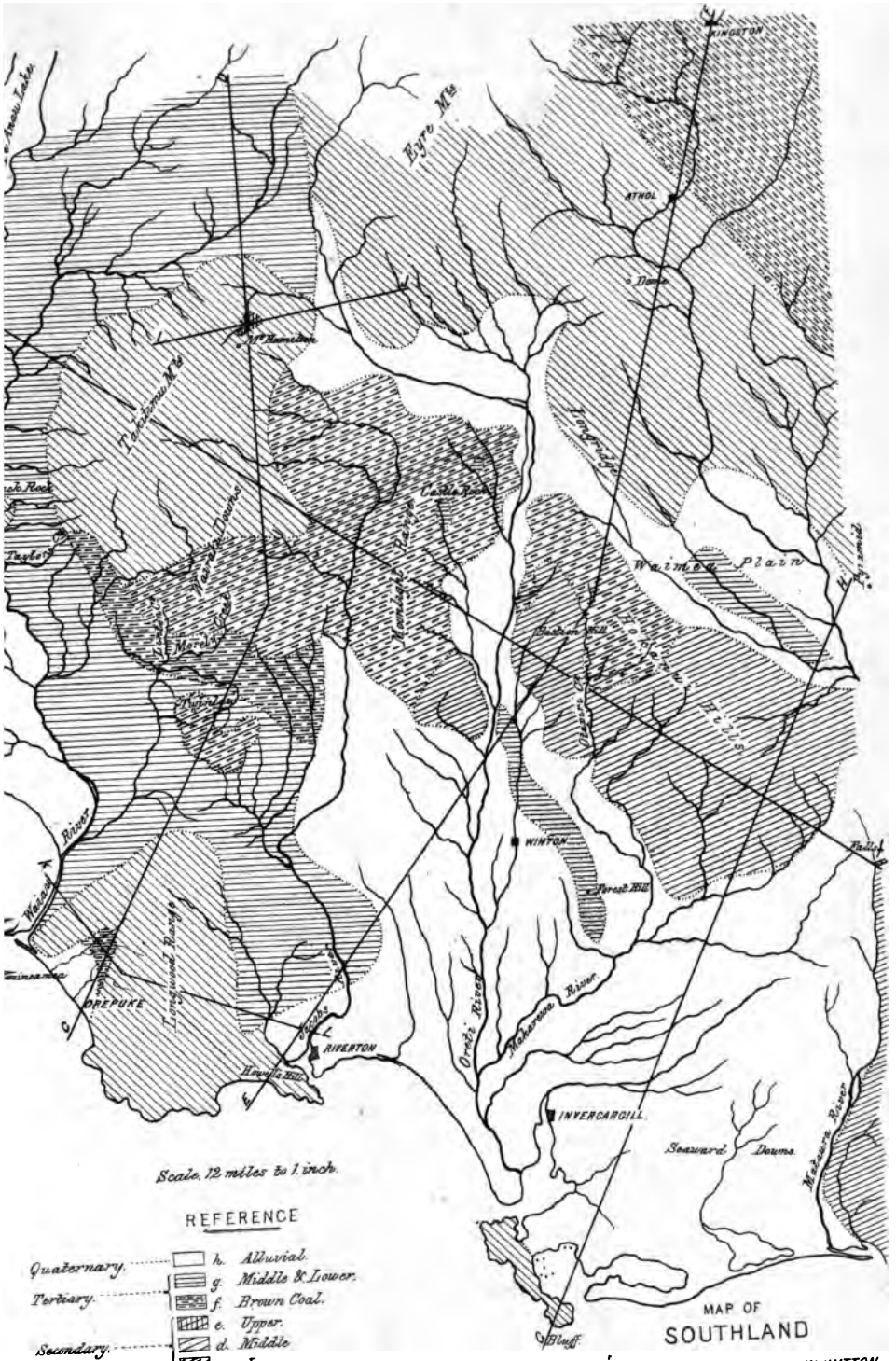
Instructions to Captain Hutton by Dr. Hector.

I AM directed to employ you in obtaining a report on the present state and prospects of the following coal mines :

1. Kawa Kawa.
2. Wangarei.
3. Waikato.
4. Hauraki.

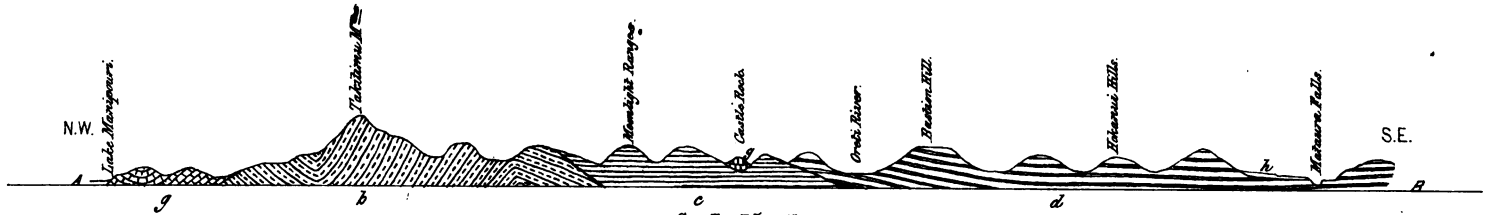
1.—At the Kawa Kawa mine you will be good enough to ascertain and report (*a*) the amount of excavation that has been done; (*b*) the quality and thickness of the seam in different parts; (*c*) estimated quantity still available "level free" or within 600 feet of the surface; (*d*) whether any steps could be taken to ascertain the existence of coal seams in other and more accessible positions.

You can refer to sheet 1 of the sketch map of the geology of the district, which I furnished to the Superintendent of Auckland in 1866, on which an attempt was made to show the above areas. This map shows that the steep hills that surround the Bay of Islands south of Waitangi, are composed of slate rocks. The Kawa Kawa river cuts through this range, and affords easy access to the later stratified and volcanic rocks that lie along the west side of the range. The formation of the valley of the river appears to have been formed by the existence

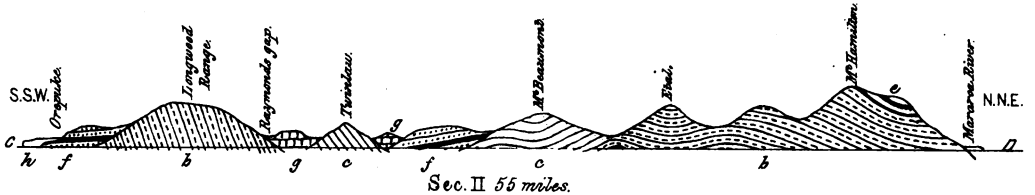


MAP OF SOUTHLAND

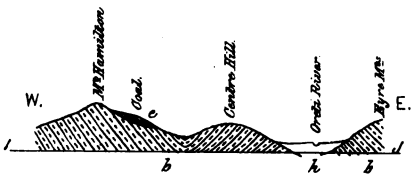
TO ACCOMPANY REPORT BY CAPT F. W. HUTTON.



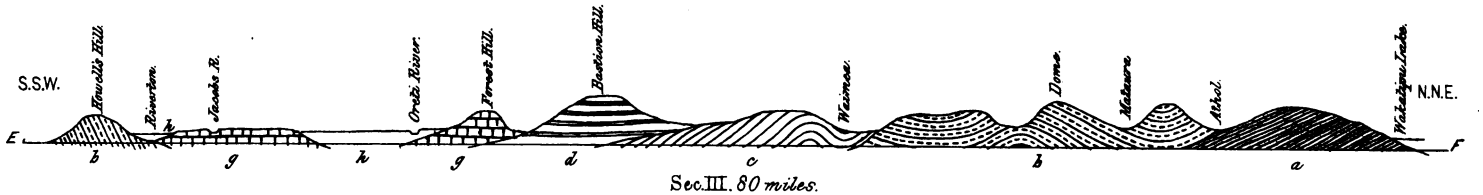
Sec. I. *75 miles.*



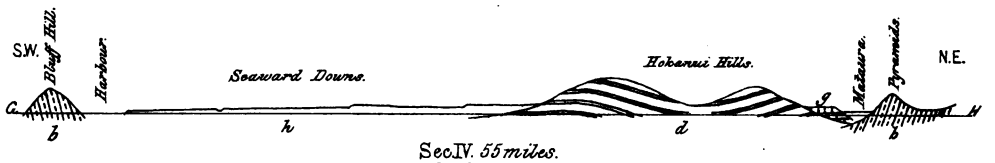
Sec. II *55 miles.*



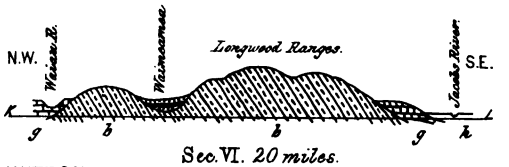
Sec. V. *10 miles.*



Sec. III. *80 miles.*



Sec. IV. *55 miles.*



Sec. VI. *20 miles.*

J.B. lith.

GEOLOGICAL SECTIONS OF SOUTHLAND BY CAPT F. W. HUTTON.

of a fault, as on the north side there is a steep scarp of slate rock rising 500 feet above the river, while the south side of the valley is a gentle slope formed by stratified deposits resting at a low level on the denuded surface of the slates.

The high slate ridge on the north, forming the Kawa Kawa block, is a plateau with steep sides, except to the N.W., in which direction it slopes gently to the Waimate basin.

Sandstone beds (with coal ?) occur on the top of the plateau at a higher level than they should do, if the strike observed on the south were continued across the valley.

Sheet 2 was a plan from actual compass survey of the coal-fields from the data which were available in 1866, showing the line of outcrop, and relative position of shafts and bore holes.

It is desirable that this map should be brought up to date by the addition of any further information and plans of the late workings.

The line of outcrop is pretty clearly indicated by the form of the ground. The underlying green slate sandstones are well seen in the tram cutting and valley of the Waiomio Creek, and I saw no reason to suspect any local disturbance or "dyke" influence near the outcrop, which could account for the de-hydration of the coal. Up the Waiomio, heavy conglomerates appear to rest on the slates and replace the coal, or has the coal been denuded off before this deposit?

Sheet 3 shows the position of the various borings that were made, and may be useful for comparing with the underground workings.

In 1866, I reported that the works necessary for opening up the mine would be of a very expensive character, even if the most favourable anticipation of the extent and purity of the seam were realised. For a short time the coal might be extracted by a level drive from the edge of the swamp, and during that time the mine would drain itself and the haulage would be cheap; but it would soon be necessary to put down a well-lined shaft forty to sixty fathoms deep, and powerful pumping machinery would be required in order to produce a sufficient quantity of coal to cover the heavy outlay necessary to convey the coal to the shipping place.

Considering these difficulties, I stated that it would not be advisable in my opinion to commence any imperfect system of mining, but until there is a prospect of being able to raise and dispose of at least 500 tons per month to defer opening the fields and wait for the future settlement of the country, when such works will be less expensive, and a local market will exist.

2. *Wangarei.*—Mr. Bidlington is engaged in boring for coal seams at that place, and if you consider that his work is likely to assist in the discovery of useful coal, if properly carried out, I will be prepared to recommend that Government should assist his efforts. You will endeavour to get a plan of Walton's mine, and any statistics of the out-put, &c., that are available.

If you pass overland from the Bay to Wangarei you will have an opportunity of seeing the coal seams at Hikurangi, of which there are four or five, but unless some sinking or driving has been done since I was there, it will not be worth while your making a special visit to that place.

3. *Waikato and Drury.*—You will gather any information respecting these mines that is not embodied in your previous reports, and make any practical suggestions that occur to you respecting the application of the Drury and Waikato coal for the railway service.

4.—*Hauraki.*—A full report on the coal seams at this locality, with a sketch plan showing those favourable for access, extent, &c., is required.

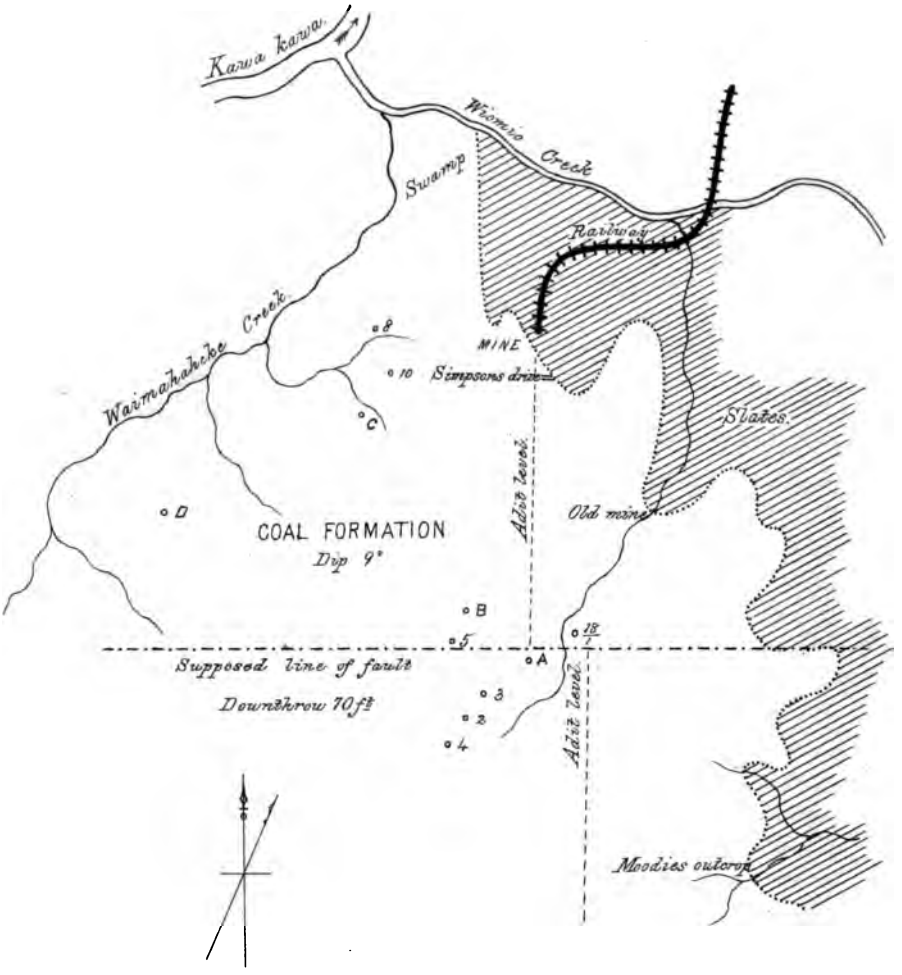
REPORT ON THE COAL MINES IN THE PROVINCE OF AUCKLAND, BY CAPTAIN HUTTON.

29th April, 1872.

Kawa Kawa, Bay of Islands.

Since the present company took over this mine they have opened it at the outcrop of the coal on the Waiomio Swamp, as recommended by Dr. Hector, and have been working it by a gallery from this point along the strike of the seam in a N. by E. (true) direction. After driving for about twenty-seven chains, the coal got thinner, and was found ultimately to be cut off by a fault. At the same time the coal was also being worked below the adit level, near the entrance to the mine, where the seam is 12½ feet thick, and the coal of superior quality, but ultimately water broke in in such large quantities that their small pump could not keep it under, and this part of the mine has had to be abandoned until large pumps are erected.

The occurrence of the fault just mentioned was first pointed out by Mr. R. W. Moodie, C.E. (Copy of Correspondence relative to Kawa Kawa Mines, A. No. 11., Report to W. Weaver, Engineer-in-Chief, 30th November, 1865), who was employed by the Provincial Government of Auckland to report on the coal seam. It appears to run in



PLAN

OF A PORTION OF THE

BAY OF ISLANDS COAL FIELD

BY CAPTAIN F. W. HUTTON.

Scale. 18 chains to an inch.

an east and west direction, passing at a short distance south of Moodie's bore-hole, No. 18-1 and north of his bore-hole No. 3, and to have its down-throw to the south.

In order to prove the position and throw of this fault a bore has been put down about half way between Moodie's bore-holes Nos. 18-1 and 3, on the line of strike of the coal from the level of the Waiomio Swamp, and at about 100 feet above this level. The bore went through—

	Feet.
Grey sandy clay	45
Hard grey calcareous sandstones	52
Green sandstone	71
Coal	7
	175

This boring must therefore be on the south side of the fault, and the throw of the fault must here be about sixty-eight feet.

As the outcrop of the coal known as Moodie's outcrop was found by Dr. Hector to be about seventy feet below the level of the first seam, it is probable that this difference of level is also to be accounted for by the same fault, and that therefore there is no evidence of a second seam underlying the one at present worked. A bore is now being commenced, at a spot near Moodie's No. 5 bore-hole, which is expected to be on the north side of the fault, and which will therefore prove, within certain limits, the direction in which it crosses the field. The altitude of this bore-hole has not yet been ascertained, but, should it prove to be on the north side of the fault, it will probably reach the coal at about 200 feet.

It is then intended to bore at the place recommended by Dr. Hector in 1866, near the Waimaheka Creek, where the coal should be reached at a depth of about 300 feet; and also at the place proposed by Mr. Moodie, higher up the creek, where the coal should be reached at about 600 feet.

These bores will prove an area of seventy-five or eighty acres, and will give confidence to the company to undertake the outlay which will be necessary before the mine can be put in proper working order.

As no survey has been made of the mine, and as a large part of it is at present flooded, it is impossible to estimate with accuracy the amount of excavation that has been done, but the manager informed

me that about 90,000 tons had been taken out, and that he estimated that about 40,000 tons more remained above adit, and to the north of the fault. The seam varies from 16 to 7 feet, the average being about 12½ feet in thickness. The average dip is W. by N. 1 in 6.

I do not think that any more accessible position than the present one could be found for working this field, especially as three miles of railway have been already made from the mine to water carriage. I am also of opinion that the existence of the fault crossing the field will not deteriorate the value of the mine; for although, on the one hand, a certain amount of driving through the overlying sandstone will have to be done, in order to connect the two sides of the fault, on the other the down-throw of seventy feet will extend the area of the field, and as this portion will be at a lower level it will probably have a more solid roof than that portion above adit; and the badness of the roof has been, up to the present, a cause of great expense in working the mine.

Whangarei.

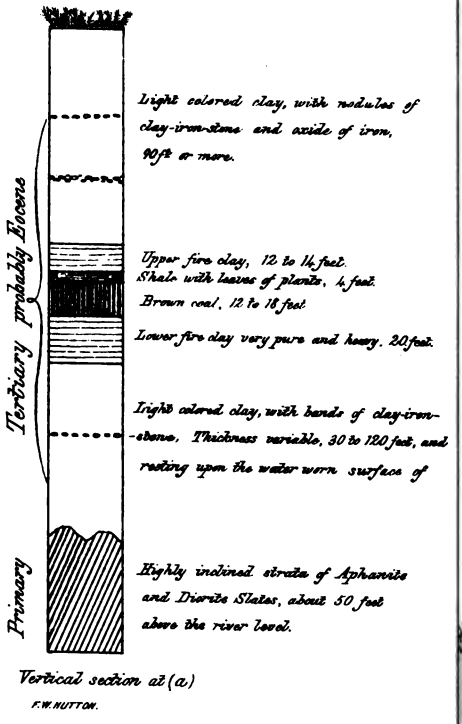
The mines at Whangarei have been abandoned for about six years, and there is, I believe, no intention of reopening them.

Superior coal was found some time ago on land belonging to Mr. Frater, on the east side of the range towards Ngunguru, and Mr. Bedlington, C.E., has since traced the formation westward towards Whangarei harbour, and he is now boring in land belonging to Mr. Dent on the banks of the Awaroa, a small stream running into Whangarei harbour, about three miles north of Grahamstown. The position of the bore hole is about a mile and a half up the stream. At the time of my visit the bore was down 209 feet, through brown sandstone with numerous casts of marine shells, and Mr. Bedlington expected to reach the coal at a depth of 240 or 250 feet.

Waikato.

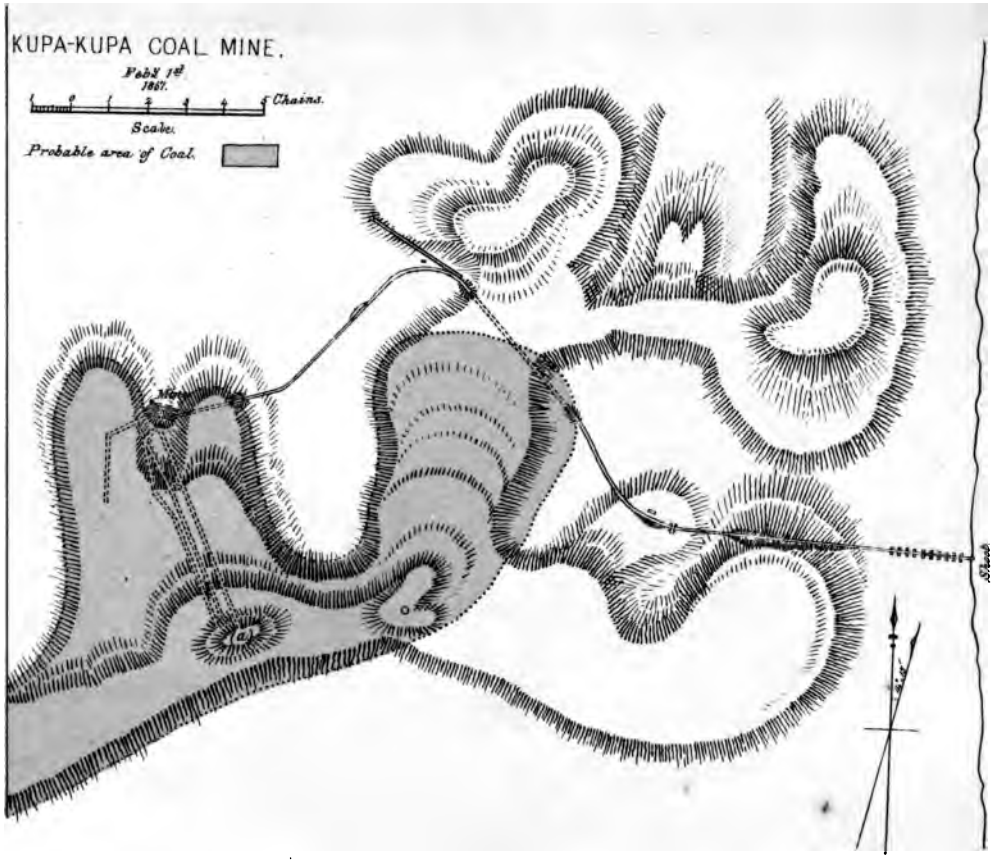
No material alteration has taken place at this mine since I surveyed it and reported upon it in 1867. Two bore holes have been put down, which prove the coal to be horizontal. The principal defect of this mine was the height of the shoot, which broke up the coal unnecessarily when loading barges. This is now being rectified by making a new tramway on the southern side of the spur, and by opening up the seam in that direction.

For further information on this and on the Drury coal-fields, see Trans. N.Z. Inst., III. p. 244.


Tertiary probably Eocene
Primary
Light colored clay, with nodules of clay-iron-stone and oxide of iron, 90ft or more.
Upper fire clay, 12 to 14 feet.
Shale with leaves of plants, 4 feet.
Brown coal, 12 to 18 feet.
Lower fire clay very pure and heavy, 20 feet.
Light colored clay, with bands of clay-iron-stone. Thickness variable, 30 to 120 feet, and resting upon the water worn surface of
Highly inclined strata of Aphanite and Diorite Slates, about 50 feet above the river level.

Vertical section at (a)

F.W. HUTTON.



Drury.

The coal mines at this place have been abandoned for about eight years, and the works have all fallen in. The Hon. H. Chamberlin, M.L.C., the owner of the property, has been making further exploration by boring, but nothing has as yet been discovered that would, in my opinion, warrant the reopening of the mine.

I have been informed by the former manager that the uneven surface of the under clay, the badness of the roof, and the high freight to Auckland, were the principal causes of the mine being abandoned.

Note.—Mr. W. H. Williams, manager of the Kawa Kawa Coal Mine, has furnished a section of the strata passed through in the bore hole, referred to in page 115, and which was completed on 17th July. The beds he enumerates may be thus grouped—

	Feet.
Grey sandy clay and surface beds	74
Calcareous sandstones, limestones, and calcareous partings	163
Green sands, with calcareous bands and conglomerates	35
Coal	5
Fire clay	5
	282

REPORTS ON GOLD MINES IN PROVINCE OF MARLBOROUGH.

BY DR. HECTOR.

Sutherland Mine—Wairau District.

12th May, 1872.

This mine is situated about four miles west of the Wairau River, at the Narrows, on a tributary called Bartlett's Creek, and between a lower range of hills, called Adam's Range, that skirts the Wairau river and the main range dividing the watershed of the Wairau from the head waters of the Wakamarina and other streams that flow to Pelorus Sound.

Adam's Range is encompassed by Bartlett's Creek and the Onamarutu Creek, which flow in opposite directions in deeply excavated vallies, for some miles almost parallel with the Wairau, until they break through and join that river at a distance of eight miles from each other, the source of the south branch of the Onamarutu being separated from that of Bartlett's Creek by a narrow ridge which connects Adam's Range with the main range.

Adam's Range is composed of felspathic and micaceous schist rock with laminæ of quartz, very unequal in thickness, and rarely contorted, except in the eastern part of the range. The formation is identical with that of a large area in the interior of the Province of Otago, and the surface features bear a marked resemblance to that country. Deep winding gullies penetrate the range, with swampy bottoms that support a rank growth of raupo and phormium. The schist rock is so friable that the smallest sized streamlets have been able to excavate deep gullies.

The soil on this range consists of comminuted fragments of the rock, and bears a scanty vegetation of fern, Manuka, Veronicas, Pimelias, and

on the hill tops, where the ground is moister, Celmisias and other sub-alpine plants that thrive on wet soil. In the gullies patches of birch bush remain, being remnants of the forest that at one time occupied all of these vallies.

The schistose hills reach an altitude of 1,800 feet, and when seen from the opposite side of the Wairau Valley, appear rounded, with the surface furrowed in a very characteristic manner. The main range to the west, on the other hand, is more than twice that height, and has a very steep abrupt slope.

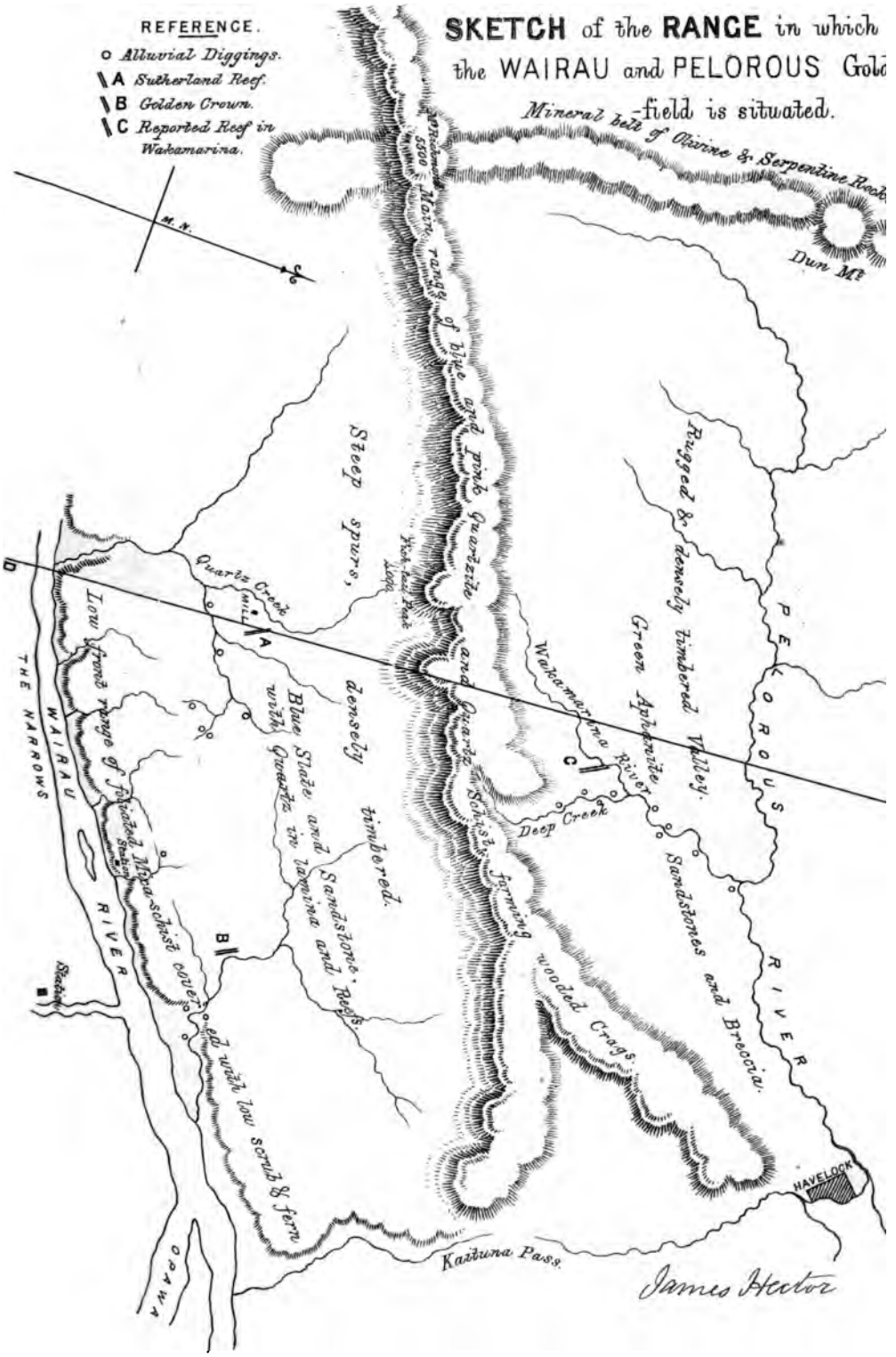
The schists are distinctly foliated with an average dip at 50° to 70° towards the west, the quartz laminæ lying in the same direction; but they are also cut by joints, the planes of which are vertical, and run E. and W., or at right angles to the strike of the foliation.

The strike of the foliation and original bedding of the work is not constant, but varies from N. to N.E.

On descending from the summit of Adam's Range to the west, and crossing the valley of Bartlett's Creek to where the mine is situated, there is a change in the formation to finely laminated blue slates, containing only a small quantity of quartz and mica, and which weather on the surface of the steep spurs to red or pale fawn-coloured splinters.

These slates dip at 70° to the N.W., and it is this part of the formation that contains the Sutherland reef, which crops out on the crest of a very narrow spur from the main range, at an altitude of 900 feet above Bartlett's Creek. It crosses the spur, which lies N. and S. obliquely, so that it would run out on either side, and besides having been exposed by a shaft and several open cuts on the crest of the ridge, it has been reached by a tunnel 130 feet below the top on the north side, and by a second tunnel 100 feet lower down on the south side.

From the lower drive a tram incline, worked with a break, has been laid for twenty-two chains to the crushing mill, which is built beside Quartz Creek, a large tributary of Bartlett's Creek. The motive power is obtained by a water-wheel, thirty-five feet in diameter, a splendid piece of workmanship, which was brought from Auckland. I had not an opportunity of inspecting the batteries, but, from the size of the building, I should judge that the tables are rather short. The creek is a large stream with a heavy fall, so that there is abundance of power. A store and accommodation house, marked "Post Office," and a few ruinous huts and neglected gardens are on the opposite side of the creek


REFERENCE.
o Alluvial Diggings.
A Sutherland Reef.
B Golden Crown.
C Reported Reef in Wakamarina.
SKETCH of the RANGE in which
the WAIRAU and PELOROUS Gold
-field is situated.
Mineral belt of Olivine & Serpentine Rock
Dun Mt
M. N.
Riccarton
5500
Main range of Blue and pink Quartzite
Steep Spurs,
densely timbered.
Rugged & densely timbered Valley.
Green Apple-rite
PELOROUS
RIVER
Wakamarina River
Deep Creek
Quartz Creek
MILL
A
C
B
D
Low fronts range of Talcoid Mica-schist
Blue Slate and Quartz in laminæ and Sandstone Reefs
Sandstones and Breccia.
wooded Crags
Station
THE NARROWS
WAIRAU
RIVER
HAVELOCK
Kaituna Pass
OPAWA
James Hector

from the mill, but there was no one living there, apparently, to take charge of the property.

I was only able to examine the reef at the outcrop, where it runs N.W. and S.E., and in the last-mentioned tunnel, and found it to be a clear body of white quartz, from one to two feet in thickness, running more east and west than on the surface, and dipping at 10° from the vertical to N.E. The reef is thus at right angles to the mass of the highly metamorphic schists lying to the eastward, but not having been traced on the opposite side of the valley, the evidence is at present against it entering these rocks.

In the direction in which the reef would be looked for on the surface of the hills to the eastward, there were, however, at one time very good alluvial diggings—several gullies, judging from the abandoned workings, having been thoroughly sluiced to within a few hundred feet of the top of the range. From this I infer that there was most probably an auriferous reef in that part of the formation which has been denuded.

I also saw alluvial workings in Bartlett's Creek, and again in Quartz Creek, where these streams wash the spur containing the reef, and also on all favourable flats on the main stream below the junction.

Although I was informed that within the last two years about 200 to 300 men have been at work in the district, yet the claims are now altogether abandoned, so that I had no opportunity of seeing the character of the gold that was found, to determine whether it is rough or whether it is much water-worn; but the other circumstances observed indicate that the spur in which the Sutherland reef occurs is a centre from which the alluvial gold was dispersed.

The auriferous character of the reef itself has also been determined.

From a return that was given to me by one of the directors of the company, it appears that one ton of stuff from the old or upper tunnel, crushed at Collingwood, gave 1oz. 5grs., and another crushing from the same tunnel of four tons gave at the rate of 12dwts. per ton.

From the new and lower tunnel one crushing of four tons gave only 1dwt. per ton, and another crushing at the company's own mill of eighty tons gave only 1gr. per ton.

This last crushing was performed under very disadvantageous circumstances, during a frost so intense that it was with difficulty that the tables and water-wheel were kept free from ice; and by examining the tailings, which were sent to Wellington for the analysis, I found that a large

quantity of mercury from the battery had escaped, carrying with it a certain amount of gold.

I append a copy of my reports on these tailings.

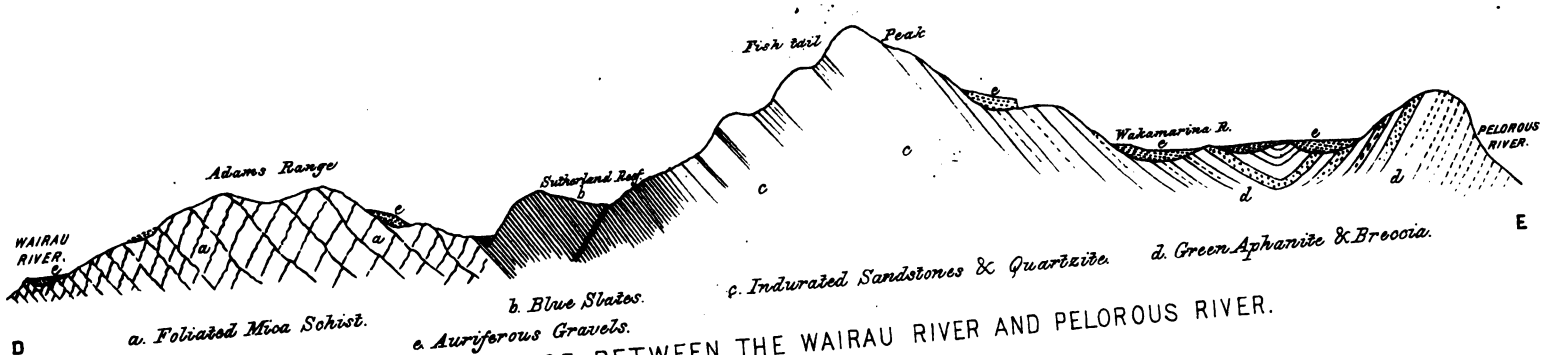
It thus appears that from every trial that has been made a certain amount of gold has been obtained, and although it was, no doubt, more convenient for the working of the mine to open the lower drive, I think it was a mistake not persevering with the working in the old drive, where payable gold had been actually obtained. The lower drive was a judicious undertaking in order to prove the persistence of the reef, but it should not have been expected that there the reef, when struck, would necessarily be as rich as there is reason to believe it is in the upper and first opened part.

By the lower drive the reef has been proved to occupy the position which was expected from the outcrop, which I think is a favourable result; and, as I judge from the tramway having been laid to the lower drive, it was intended to work the mine from it, it now only remains to push forward the drive till the reef is thoroughly tested.

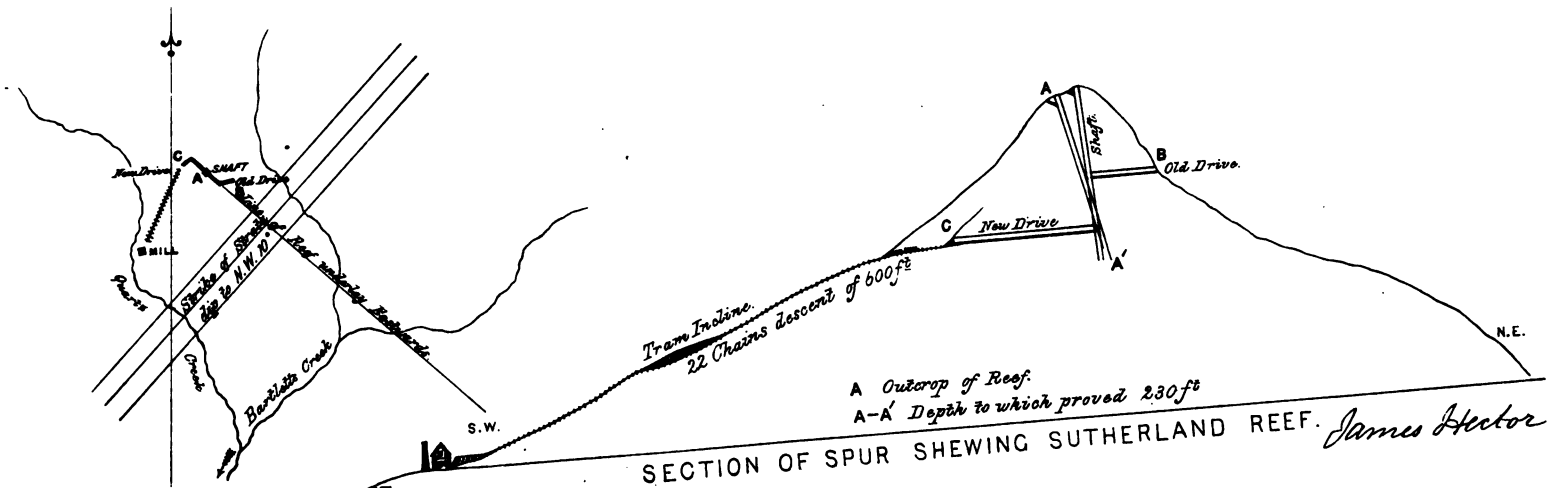
The quartz in the lower drive is very white and sugary, and the inclosing slates are of a deep blue colour, and fall rapidly on exposure to the air. In all parts of the reef and the inclosing rock which I was able to examine there is a deficiency of iron pyrites, but I should state that like reefs occur in a very similar rock formation in the Inangahua district, in which experienced miners put great faith.

Although I do not see anything which leads me to believe that the mine will prove very rich, I am of opinion that the company, having gone so far as to erect expensive machinery in a very inaccessible position, and having had the mine well opened by drives, and everything put in working order, and considering that a certain amount of gold has been obtained, it would be desirable that a proper trial of the mine should be made before it is abandoned. Up to the present time no sufficient test has been obtained of stone from that portion of the mine that afforded the best indications, and the shareholders appear to have been disheartened by the unprofitable result of a single large crushing of stuff taken from a place where no favourable prospect had ever been obtained.

In a direct line across the dividing range is the Wakamarina River, where very rich alluvial diggings were discovered in 1864, and which still give employment to a few men. I have been as far up that river



SECTION OF THE RANGE BETWEEN THE WAIRAU RIVER AND PELOROUS RIVER.



PLAN OF SUTHERLAND REEF.

SECTION OF SPUR SHEWING SUTHERLAND REEF. James Hector

as the junction of two large branches, and found that gold was obtained in terraces along the sides of the valley and in the river bed, the auriferous gravel everywhere resting on water-worn bars and ledges of greenstone slate and aphanite breccia.

From the wash in other streams traversing the same formation being barren of gold, I infer that in this instance it must have been derived from some distance, or from towards the source of the stream in the central range, on the opposite side from Bartlett's Creek.

Onamarutu Creek is also auriferous, and there seems to have been at one time very extensive "paddock" diggings on a low saddle that has evidently been a former outlet of that stream to the Wairau. These diggings were all in full working during 1869–70, but only a few men are still at work in that neighbourhood.

From the foregoing circumstances I infer that auriferous reefs will be found in the central part of the main range, in that part of it between Bartlett's Creek and the Wakamarina; but being a densely bushed country it was hopeless for me to attempt any search with the limited time at my disposal.

A sketch plan of the district, and also of the mine, together with a section explaining the general structure of the country above described, is appended. The central range has been marked as quartzite slates, but only because the hills which overhang Havelock are of that formation and appear to lie in the same line of strike.

ENCLOSURE.—*Dr. Hector to J. B. Wemyss, Esq.*

5th August, 1871.

THE specimens which you forwarded from the Sutherland Reef have been examined by Mr. Skey, and I beg to forward the results together with replies to the questions raised in your letter of the 14th July last, respecting the probable cause of the failure of the recent trial crushing.

Tailings.—These appeared to be well pulverised, and contained a small quantity of mercury interspersed in fine globules. The whole sample sent was well mixed, and a ¼lb. was taken for examination. On being worked up to a stiff paste with water, a small quantity of mercury was added and kept in perfect contact for three hours. The mercury was then panned off and retorted, and a metallic residue in the proportion of 2dwts. per ton, one half of which may be reckoned as pure gold.

Blanketings.—These were treated in the same manner, and gave a yield at the rate of 13dwts. per ton, of which about 10dwts. would be gold.

These determinations were performed at a temperature of 50° Fah. and no difficulty was experienced in separating the mercury.

Water.—The chemical examination of the sample of water sent, shows it to be quite free from sulphate of iron or other salts that would prevent amalgamation of gold and mercury. It is in fact of much better quality than the water generally used at quartz mills.

QUARTZ.

The specimens of quartz which were first sent were too small to give any satisfactory result, but there is nothing present in them that indicates any special difficulty in milling.

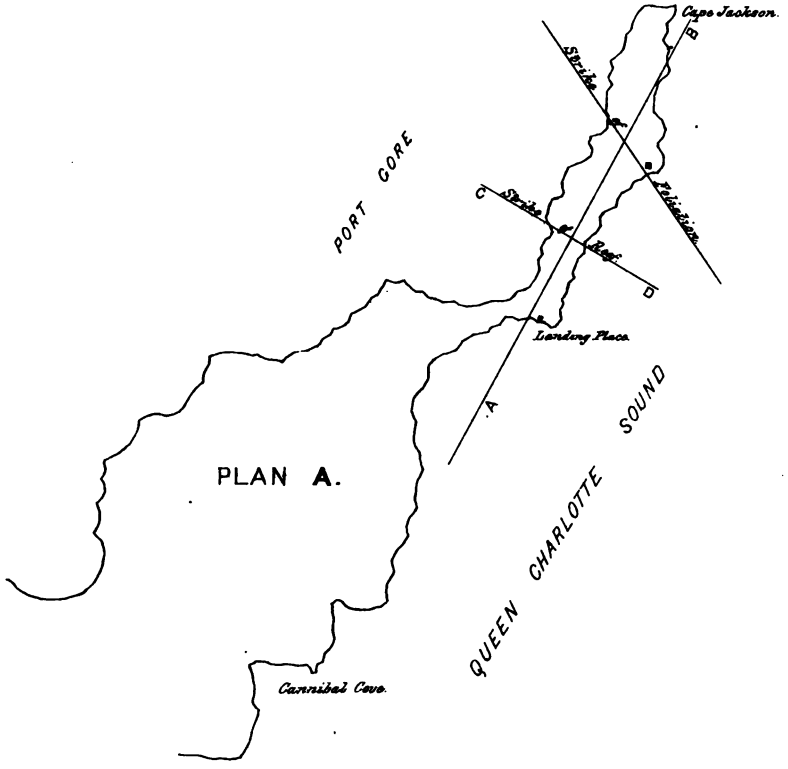
The second specimens were examined.

No. 1. From the old tunnel 115 feet below the surface, by simple amalgamation, gave at the rate of 19dwts. 12grs. per ton.

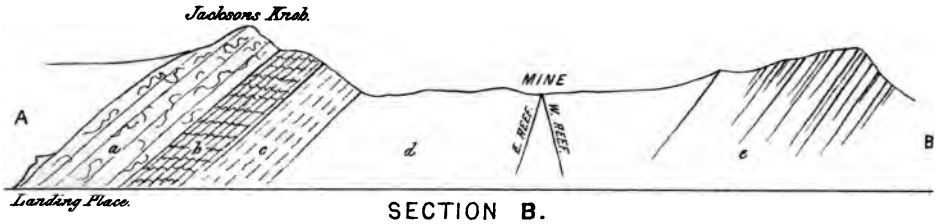
No. 2. Sample stone gave at the rate of 2dwts. 4grs. per ton, and in both cases the gold was of good quality.

From the foregoing results it appears that the supposed loss of gold sustained in the crushing is not due:—1. to any defect in the water; 2. nor to defective crushing; 3. nor to any chemical substance in the stone. I think it most probable that the defect will be found to rest with the slope of the tables, the amount of water with which the machine is fed, and probably, to some extent, the low temperature of the water. The loss from flowering of the mercury I should think due to the plates and ripples not being in order, and not to the mechanical action of the stampers. It would be advisable, however, that the mercury should be added to the stamper boxes in small quantities, and that the amount so added should not be in excess of the quantity required to form a soft pasty amalgam with the gold present. Nothing but experience of the stone operated on can decide the exact quantity required, and the intervals at which it should be added.

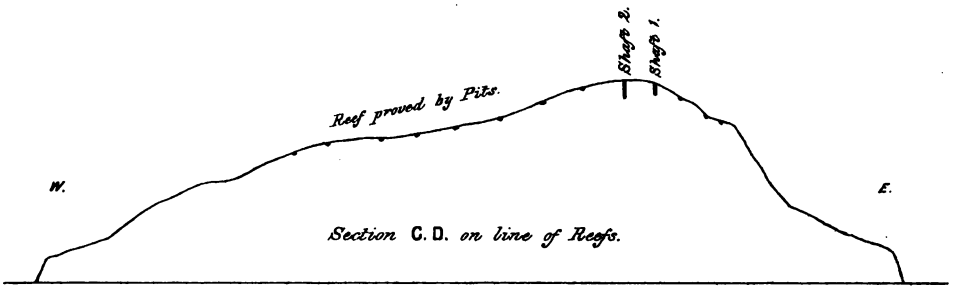
I am not able to form any opinion as to the probability of your reef proving to be remunerative, from the information you send, but no doubt you had good "prospects" from various parts of it before the expense of constructing machinery was incurred. I shall be very happy to afford any further information that is required.

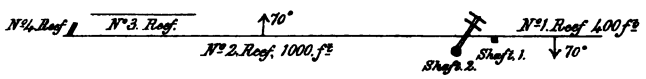


PLAN A.



SECTION B.





PLAN OF REEFS.

14th October, 1871.

You are quite correct in supposing that it is the escape of the flowered mercury and not the flowering itself that is due to the state of the plates. At the same time there is a difference between mercury in clean globules and when it is in the state known as flowered, as then the globules will not re-unite nor adhere to the amalgamated surface of other metals. I enclose a copy of Mr. Skey's report specially on the subject as observed at the Thames, from which you will see that 2dwts. per ton on the mixed stuff, or 4dwts. per ton on the quartz, is not above the average loss.

The "blanketings" you sent here would of course be rich or poor, according to the way they were sampled; therefore, unless you are quite sure that the sample was a fair average, I can hardly make an inference as to the total quantity lost, nor is it quite safe to compare the two crushings and conclude that the difference in result may be due to loss of gold, as the stone itself may vary much in richness in different parts. This is far from being unusual, and in fact at most mills hundreds of tons are uselessly crushed from want of previous sorting by an experienced eye.

The "streaking" or "sorting" table always used in South America, on which the ore is classed, is never used in New Zealand. I think it very likely from what I have seen of your stone, that only a certain part of it will be auriferous, and one of the first points you have to ascertain is, which is your payable vein-stuff.

Turner Reef Near Cape Jackson, Cook Strait.

23rd June, 1872.

This reef was discovered about two years since by Mr. Turner, who holds the promontory between Gore Bay and Queen Charlotte Sound as a sheep run. It is situated about two miles from the cape, in the position shown in the attached plan I., and half a mile from a rocky landing place, where Mr. Turner has erected a woolshed and ships his wool from.

The only way to reach the locality is by boat, either from Picton, twenty-five miles distant, or from one of the steamers as they pass between Picton and Nelson. There is no beach at the landing place, so that the boat has to be hauled up and lashed on a rocky ledge out of reach of the heavy sea which occasionally breaks there from the south-east. In north-west weather, however, there is perfect shelter, except from the

squalls and eddy winds that sweep across the narrow peninsula with extreme violence.

The nearest good beach for a boat is at Mr. Turner's homestead in Cannibal Bay, four miles further up the sound on the same side. The promontory is half a mile wide, and elevated 700 feet above the sea level, the highest point being Jackson's Knob, three miles from the extremity of the cape (plan A.)

The quartz was first discovered on the summit of this ridge, where it has an altitude of 500 feet. The rock of which the promontory is composed is a felspathic micaceous schist, the foliation of which has a steady strike N. 40° W., and a dip of 50° to the S.W. In following along the crest of the ridge the rock presents several varieties, which are shown in section B.

a. Grey sandy schist with much quartz in contorted laminæ. This is the rock at the landing place, and also on the summit of Jackson's Knob, to which it leads up by a bold spur, that appears to withstand the influence of the weather better than the other rocks.

b. Blue slate, cleaved, and also traversed by contorted laminæ of quartz crossing the cleavage plains which are parallel with the foliation. These quartz laminæ vary from the thickness of paper to that of several inches.

c. Sandy schists that break away in large slabs, and contain quartz laminæ parallel with the foliation.

d. Felspathic flaky schists that contain very little quartz, but are traversed by irregular rusty joints with a little friable quartz and oxide of iron.

These schists which are very easily decomposed contain the quartz reefs. They gradually pass into slaty schists containing contorted quartz laminæ, which form a second knob at *e*, and from underneath which sandy schists in slabs like the bed *c* again appear. The reefs cross the promontory at right angles in the low part between these two knobs, as shown in plan A.

No. 1 reef has been struck on the outcrop on the top of the hill in two shafts, and in several open cuts for 400 feet down the east side of the ridge. The first shaft is about twenty feet deep, and shows the quartz to be fifteen to thirty inches thick running N. 70° W., and dipping at 75° to the S. The reef is composed of several distinct kinds of quartz, differing in compactness and colour, and divided by smooth joints parallel with the walls of the reef. There is no clay band or soft

casing on either side of the reef, but the schists are soft and decomposed where they are in contact with the quartz.

The second shaft is slightly over the brow on the west side of the ridge, and is eighty-five feet deep to where it cuts the reef. A level has been driven for a distance of fifty-two feet to the north-east from this shaft at a depth of fifty-five feet from the surface, and cuts three veins of quartz, one of which, supposed to be the same as No. 1 reef, has been driven on for thirty feet to the E.S.E. Down the west slope of the hill what is supposed to be another reef (No. 2) has been traced for 1,000 feet. It has the same direction as No. 1, and is exactly similar to it in character, the only difference being that it dips in the opposite direction, or towards the north. As no reef with a south dip has been found on the west slope, it is probable that this is only the same reef which has been dislocated.

Parallel with the west reef, at eighty or ninety feet from it on the north side, is a strong lode of quartz three to four feet thick, which has a crystalline structure, or at least has cavities containing well developed quartz crystals. The other vein generally consists of three parts—a massive compact quartz with irregular rough fracture and full of small flattened cavities, which are coated with sulphur-coloured efflorescence; outside the compact portion there is generally a banded quartz that breaks into sharp splinters, the surfaces of which are stained with iron; on fresh fractured surfaces the quartz is frequently found to be tinted green, pink, or grey, and it is in this variety that the best specimens of gold are got.

Near the lowest point where the reef has been found on the west side a small flat leader, 1¼in. thick, has been traced for four feet on the north side of the reef, of a brown quartz, which proves to be the richest stone of any of the samples analysed, containing at the rate of about 3ozs. to the ton.

Without much searching gold was found in most parts of the reef that have been exposed, some of the specimens I have seen being very rich, containing the gold in irregular solid masses. The following specimens, in which no gold was visible to the eye, were selected for analysis:—

No. 1. A white, slightly ferruginous quartz, from the No. 1 reef, gave at the rate of 10dwts. 2grs. per ton, the gold being very light coloured.

No. 2. Quartz with a slaty structure, containing arsenical pyrites,

gave 17dwts. 8grs., also of light coloured gold. This was from the bottom of the eighty-five feet shaft on No. 2 reef.

No. 3. A reddish brown quartz, from the flat leader above referred to, and coated with a sulphur compound, gave at the rate of 3ozs. 6dwts. 13grs. of very pure gold.

Two other samples, which were submitted for analysis by Mr. Greenlaw, one of the prospectors, as specimens taken from the No. 2 reef, gave 1oz. 6dwts. 14grs. and 1oz. 1dwt. 10grs. respectively, the gold in both cases being of a light colour.

From the foregoing observations it appears that at least one auriferous reef has been traced by surface indications to cross the promontory for 1,400 feet, and for about 100 feet below the level of the crest of the ridge on the east side, and 300 feet on the west side, and also to the depth of eighty-five feet on the summit, as shown in plan and section C. D.

In so far as it is safe to judge from the analysis which has been made of the specimens taken at random from different parts of the reef, it may be expected to yield at least ½oz. to the ton.

If we suppose that the reef through the hill extends continuously to the depth to which it has been traced down each slope, then for every foot in thickness of quartz, there will be about 10,000 tons in the cross section of the promontory, at a very moderate computation, and, if the reef extends to the water level, about 40,000.

I am aware that calculations of this kind, founded on imperfect data, are very hazardous, and I only suggest this in order to show that there is a reasonable prospect of there being a sufficient quantity of reef stone in the locality to warrant the opening of a mine.

The working of the mine will be a very easy matter, as levels can be driven in almost any part of the reef from either side; but in order to crush the quartz it will be necesssry either to work a mill on the spot under great difficulties, owing to the want of a sufficient supply of fuel and water, or to ship the stone to some locality better adapted for milling it. The expense of collecting sufficient water for working the tables on the promontory near the reef, and the landing of machinery and coals under very unfavourable conditions, require to be compared with the cost on the other hand of shipping the stone, in order to determine which course should be adopted.

There are other indications of the existence of minerals of economic value on the west side of Queen Charlotte Sound besides these reefs.

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In the upper part of the sound, between the Grove and Shakespear Bay, near Picton, micaceous schists, containing a great deal of quartz, have the planes of the foliation lying W. or N.W., and dipping at from 30° to 70° to the N. or N.E. Half-way down the sound, north of Resolution Bay, the rock changes to a felspathic flaky schist with very little quartz, but containing hornblende. The foliation of these schists strikes N. and S., and dips to the W. at 30°, but they are also intersected by N.W. joints. In this formation Mr. Turner has found a lode of quartz and sulphide of antimony, also loose blocks of olivine with chrome ore, compact horn-blende rock, and white and green chert. This would indicate that the rocks in the neighbourhood, and probably the greater part of Mount Farenaux, which rises to the height of 2,600 feet, and also the large unexplored area round Mount Stokes, between Queen Charlotte Sound and the Pelorus, belong to a different formation from the prevailing schists, and that the district is therefore deserving of the attention of prospectors. A specimen of quartz-rock, obtained by Mr. Turner at Cannibal Bay, containing iron pyrites dispersed throughout its mass in small grains, yielded on analysis gold at the rate of 1dwt. per ton.

REPORT ON THE COAL MINES IN THE WESTERN DISTRICT OF THE PROVINCE OF NELSON.

BY DR. HECTOR.

22nd June, 1872.

In a former report (Geological Reports, 1867, p. 18) I divided the upper secondary coal fields in that part of the colony into—

1. The Pakawau field, which extends from near Cape Farewell southwards for about fifteen miles, occupying a great part of the surface of the mountains between the valley of the Aorere river and West Wanganui inlet.

2. The Buller, or Mount Rochfort, field, which occupies a narrow strip of mountainous country that extends southward from the Karamea river to the Buller, a distance of forty miles, with a greatest width of seven miles.

3. The Grey river and Mount Davy field, which forms a range of mountains lying to the north of the Grey river, in which direction the formation extends for seven miles to where it is intersected by the coast.

The coal formation in each of these areas has the same general character, comprising conglomerates, and sometimes an angular breccia towards the base, followed by micaceous sandstones, grits, and shales, with seams of black coal (caking anhydrous coal). The thickness of this lower part of the formation is from 200 to 800 feet. In some localities a thick bed of well-rounded conglomerate follows the above; but where this is wanting, the micaceous sands pass gradually into sandy clay marls of a dark brown colour, containing nodules of ironstone and marine fossils (limonite sandstones). Immediately beneath this marine formation, sometimes in the sandstone and at others resting on the surface of the conglomerate, is frequently a seam of coal of an inferior description, which will be spoken of as the upper coal. Its most common form in the district is a pitch coal, which is a variety of brown coal, containing a large admixture of resinous matter and a comparatively small proportion of constitutional water.

Marine formations to the thickness of at least 1,500 feet follow, consisting in ascending order of argillaceous sandstones, finely laminated marly shales, compact chalk marl, and calcareous sandstone.

In some localities the lower members of this series of marine formations are wanting, and the upper calcareous beds overlap on the basement rocks of the country, but generally having the coal formation represented by a thin intervening band of sandstones, shales, and pitch, or common brown coal seams. From this I infer that the upper coal and its associated sandstones are the horizontal equivalents of the limonite sandstones, which I have referred to as immediately following tho lower coal-bearing strata in some parts of the district.

Grey River District.

The only mine of importance which has been opened in this district is the well-known Brunner mine, six miles from the mouth of the Grey River. There is nothing to report as to this mine in addition to what has been stated in former reports, except that the workings are still quite inadequate to supply even the local demand.

The coal seam is sixteen feet thick, and has been proved, by underground workings, to be of uniform quality, without admixture with slack or other foreign matter, throughout an area of thirty acres; in addition to which, the surface indications lead me to estimate the quantity of coal which is available without sinking as at least 4,000,000 tons, the area of undisturbed coal above the water-level being more than

half a square mile. In addition to this a much larger quantity of coal can be obtained by sinking.

The extension of the coal to the north is interrupted by a fault, which cuts it off; but there is no reason to doubt that the seam will be again found at a deeper level, the downthrow being in that direction.

Up to the present time the extent of this downthrow has not been determined, but, from examination of the strata, and comparison with parallel faults which can be observed in the same formation on the sea coast farther to the north, I expect it to be less than 100 feet. On the south side of the Grey River the coal appears to be also cut off by a fault, but this has not yet been proved by underground working.

The Brunner mine can never be worked to advantage, nor afford any supply of coal to other parts of the colony, until the railway connecting the mine with the mouth of the river has been constructed; and the amount of coal already ascertained to exist is, in my opinion, sufficient to warrant the expenditure authorized for this purpose; and, from the great facilities which exist for working the mine, the coal should be delivered to vessels at eight shillings per ton.

After the construction of the railway, and the preliminary harbour improvements which have been recommended as part of the railway works, I believe that a good steam-tug for the bar service would be sufficient to enable small sailing vessels, in the first instance, to carry on a profitable coal trade with other ports of the colony, and that, if the trade expands, and the coal proves, on working, to extend over larger areas, the depth of water on the bar can be hereafter materially increased by proper engineering works.

The accompanying plan shows the relative areas of coal which are above and below the water-level, and the position of the faults.

A sample from the six-foot seam of coal that crops out on the coast six miles north of the Grey River has been analyzed by Mr. Skey, and found to be a very superior variety of pitch brown coal, resembling very much the best kind found at Shag Point, in Otago, and, like it, well adapted for gas-making, but without furnishing any true coke. It contains—

Gas and oil	55·40
Fixed carbon	34·80
Water	6·20
Ash	3·60
	100·00

It will be observed that the composition of this coal is very different from that found towards the base of the formation at the Brunner mine, which contains sixty-four to sixty-eight per cent. of fixed carbon. I mention this fact as it has been supposed by some persons that the seam on the coast is a continuation of that which is worked at the mine.

Mount Rochfort Coal Field.

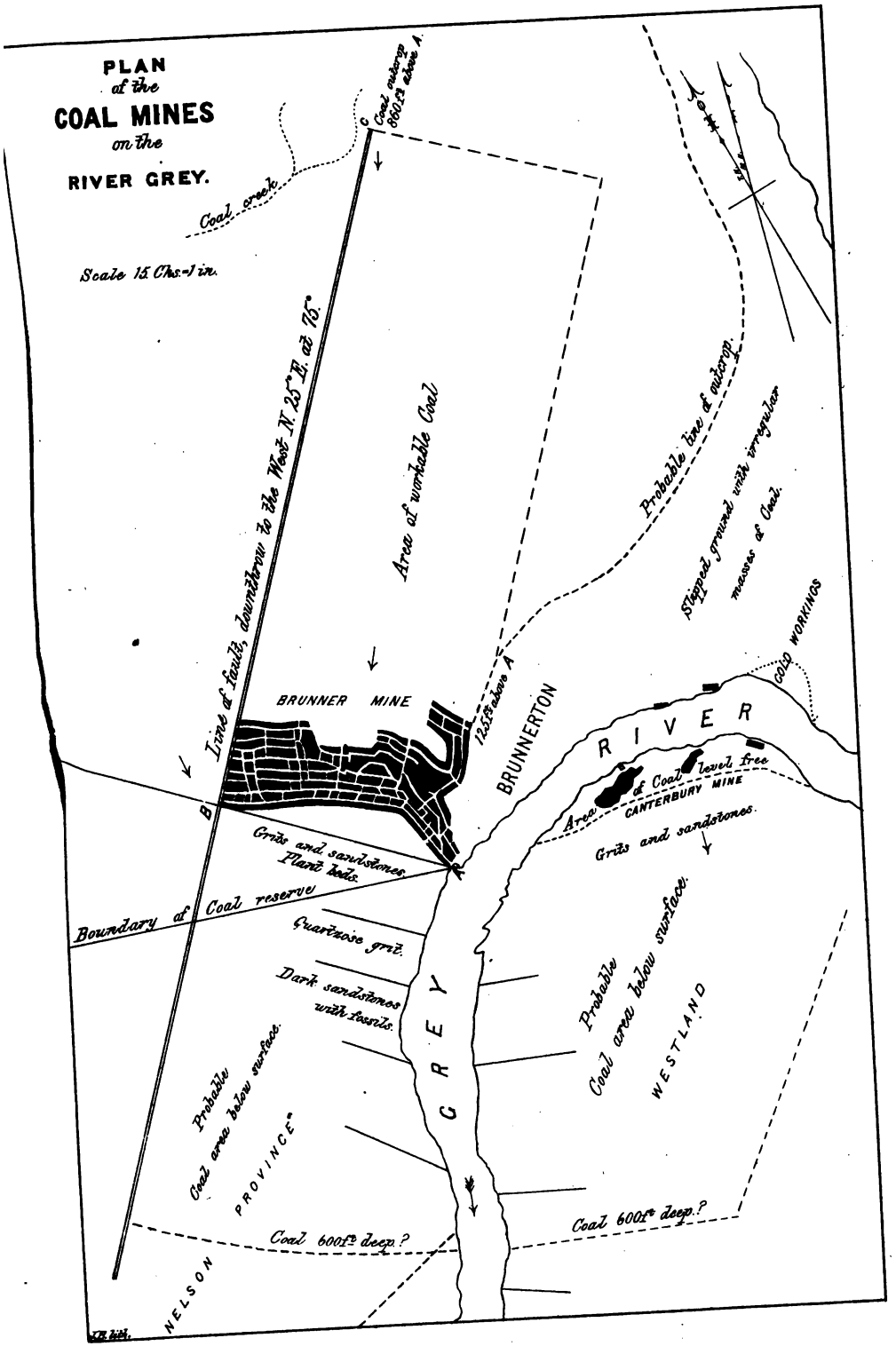
During the past summer my attention has been mainly directed to the discovery of coal mines within easy reach of Westport.

The coal formation of this area was, previously to my former examination of it in 1867, surveyed and reported on by the late Mr. James Burnett, whose excellent plans were placed at my disposal by his Honour the Superintendent of Nelson.

This coal field may be described, in general terms, as occupying an undulating plateau, or flat upland valley, the western termination of which overhangs the coast, having an elevation of from 1,500 to 2,500 feet near the Buller, while in the other direction it slopes to the north-east, and descends to the sea-level at the Mokihinui.

Viewed from the sea coast the coal formation is seen to commence at Mount Rochfort, which presents a cliff of conglomerate, 700 feet high, three miles inland, facing the south. From this point northward there is a dip in the level, in the centre of which is the deeply cut gorge of the Waimungaroa, but the plateau surface does not reach lower than 1,500 feet above the sea. The formation again rises, behind and to the eastward of Mount Frederic, to 2,800 feet, and dips again to the Ngakawau, when the plateau surface is only 1,000 feet above the sea. A long ridge of granite then extends to the Mokihinui, beyond which the coast is formed by the upper marine formations. The general features of this district are shown in the attached plan and sections.

Many outcrops of a seam of hard, pure coal, from eight feet to sixteen feet in thickness, have been discovered on this plateau, but all at such an elevation as to require engineering works of a costly nature to reach them. A search has therefore been made, with a view of finding a seam in a more accessible position, and with this object the lower gorge of the Buller River, where it cuts its way round the south end of the plateau, was examined, as it has very naturally been supposed that the coal seams might be there found at a lower level and in an available position.


PLAN
of the
COAL MINES
on the
RIVER GREY.
Coal creek.
Scale 15 Chs.=1 in.
Coal outcrop 860ft above A.
Line of fault, downthrow to the West N 25° E. at 75°.
Area of workable Coal
Probable line of outcrop.
Slipped ground with irregular masses of Coal.
COLD WORKINGS
BRUNNER MINE
1255ft above A
BRUNNERTON
RIVER
Area of Coal level free
CANTERBURY MINE
Grits and sandstones.
Plant beds.
Boundary of Coal reserve
Quartzose grit.
Dark sandstones with fossils.
Grits and sandstones.
GREY
Probable Coal area below surface.
WESTLAND
PROVINCE
NELSON
Coal 600ft deep?
Coal 600ft deep?

Lower Buller Gorge.

This gorge commences nine miles from the mouth of the river, and for five miles the hills on both sides are formed of granite.

Towards the south, in the direction of Mount Rochfort, the granite spurs rise to the height of at least 1,500 feet above the river; the coal formation lying on the top of this range and five miles back from the river.

The valleys in that direction are extremely narrow and rugged, and offer no favourable line of access to the plateau.

In ascending the river, the granite is succeeded, after a narrow band of mica schist, by a massive conglomerate and breccia formation, forming hills 1,400 feet high, the spurs of which are equally inaccessible with those of the granite formation, and terminating frequently perpendicularly towards the river, so that at one place, called the Hawk Crag, it has been found necessary to cut the horse track like a half section of a tunnel, along the face of the precipice. This great conglomerate, which is quite a local formation, without parallel in any other part of the district, crosses the valley from north to south, and rests unconformably on the coal-bearing strata, which commence just before reaching the Blackwater and continue to Granger Point, where the valley opens out for some distance; and the overlying marine formations, which run in a north line from the Inangahua Junction to the coast at the White Bluff, north of the Mokihinui River, commence to form lofty mural bluffs of chalk, marl, and tabular limestone.

In the lower part of the coal formation at this place, only obscure fossil plants and thin seams of coal were found; but in the higher part of the section, and overlying the conglomerates, the seam of coal occurs that was referred to by Mr. E. J. O'Conor, M.H.R., in his evidence before the Select Committee on Colonial Industries (Parliamentary Paper, H. 7, 1871, p. 17). This seam is exposed in several places in Coal Creek, a tributary of the Buller from the south. The coal, which is compact brown coal, containing masses of fossil resin, is at least 16 feet thick, and dips to the south-east at 10°, under a compact brown micaceous sandstone that contains leaf impressions. Its composition, from several analyses that have been made in the laboratory, is as follows:—

Fixed carbon	41·94	50·80
Gaseous matter	36·97	25·54
Water	13·93	16·46
Ash	7·16	7·20
	100·00	100·00

It is compact, hard, with a dull lustre, and is very different in appearance from that found in the plateau, being, in fact, a brown coal, containing an unusually high percentage of fixed carbon, but still containing too much water to be employed for sea-going steamers. This coal will not, therefore, justify any large expenditure for the purpose of taking it to Westport, and even were it equal in quality to that found on Mount Rochfort, I doubt if it would pay, at the present time, to construct a railway line through the gorge for such a purpose; while, on the other hand, the great risk of running the rapids with heavily laden boats will prevent any large quantity being conveyed by water carriage, even as a return cargo by the barges that at present take the goods up country.

In the valley of the Inangahua coal occurs at several places, the sandstone formation crossing the river seven miles from its junction with the Buller. At this point there is a seam of pitch coal, the thickness of which was not ascertained, and the same seam appears again to rise towards the east from beneath the marl stones on the creek. The coal seam on Murray Creek deserves mention, although the locality is too far inland to allow of the coal being available for other than local use at the present time. This stream is a branch of the Inangahua River, on which the alluvial diggings were first worked which led to the discovery of the reefs in this vicinity. The creek has a short course of about three miles, and at its upper third cuts through a bed of fine coal, not less than 20 feet thick, and perhaps more. The seam dips to south-east at 10°, and rests on a floor of brown sandy shales and tough sandstone, which again rest unconformably on the green and grey slaty sandstones which form the matrix of the quartz reefs. The coal seam is covered with thick beds of grit and sharp quartz sandstone, like that on Mount Rochfort. This coal is now excavated for supplying the steam quartz mills. Its quality is excellent, as shown by Mr. Skey's analysis of two different specimens:—

Fixed carbon	(*a*)54·52	(*b*)54·94
Hydro-carbon	39·31	33·70
Water	4·98	10·38
Ash	1·19	·98
	100·00	100·00

(*a*.) Is a compact coal, with a bright lustre and splintery fractures, resembling some of the Mount Rochfort coal, but to which it is inferior

Waimangaroka R.
Coalbrook Dale
Buller R.
B
Coal Creek
C
d
Hawke's Crag
COAL
b
B
3400
Mt William
David Creek
Orikaka
Cascade R.
Coal Brook Dale
1900
3270
Mt Rochfort
Bore hole
1000 ft.
Mile Creek
a
BULLER RIVER
WESTPORT
Orawaite R.
D
Mt William
Coal Brook Dale
Waimangaroka R.
10 inch Coal

in the smaller proportion of carbon, and not forming so coherent a coke.

(*b.*) Has more the fracture of a brown coal, and looks like jet.

The Murray Creek coal must be considered as intermediate in value between the pitch coal and the bituminous coal of the Brunner mine.

Mount Rochfort Plateau.

This is a basin-shaped area, having an extent of about fifteen square miles, and included between Mount Rochfort (3,270 feet altitude) on the south, Mount William (3,400 altitude) on the east, and Mount Frederic (3,000 feet altitude) on the north-west.

To the north-east it slopes gradually to a low saddle between the Orikaka and Mokihinui Rivers. It also slopes, but very abruptly, towards the west through the depression between Mount Rochfort and Mount Frederic, and also towards the south-west to Ngakawau.*

The arrangement of the coal formation is very irregular on this plateau, but, disregarding minor inequalities, it appears to be as follows :—A syncline, or rather a trough-like valley, the axis of which is inclined to the north, commences at the saddle between the heads of the south branch of the Waimangaroha and the streams flowing south to the Buller, and between Mount Rochfort and Mount William, and, passing to the east of Mount Frederic, reaches the coast above the Ngakawau. This trough appears to carry the heaviest seam of coal, but its dimensions and extent are not yet ascertained.

Lying to the west, and somewhat parallel to the above, the remains of a second synclinal exist, the eastern side of which is represented by a patch of the formation which dips south-west from Mount Frederic, and the western side by the strata towards the base of the seaward slope of Mount Rochfort, which dip to the eastward. The summit of Mount Rochfort itself, which is a barren mass of conglomerate without coal seams, may be looked on as the anticlinal ridge between these troughs; but north towards the Waimangaroha Gorge the coal formation has been denuded, and granite and slate appear at the surface, completely cutting off the extension of the coal seam across the plateau.

To the west of this outcrop of the underlying rock, only a 16-inch seam of coal has yet been found. In using the above terms to describe the above arrangement of the strata, it must be understood that these troughs have arisen in a great measure from original inequalities of the

* Ngakuwaho on the map; but according to the Maoris Whangakawau, or shortly, as above.

surface on which the coal formation was deposited, probably as a great lacustrine drift, so that a coal seam found in one depression will not necessarily extend into an adjacent one, and this is shown by the manner in which the upper grit beds, which overlie the coal, thin out against the slate patch in the centre of the plateau.

The disturbances that have affected the formation since its deposit are so abrupt as to have more of the nature of faults than plications, a point of great importance in the practical working of the coal field. A most remarkable instance of this is offered by Mount William, on the top of which (of 3,400 feet altitude) the coal and accompanying strata, 200 feet thick, are found dipping at 15° to the north, while due west, at a distance of 60 chains, and 1,800 feet less elevation, the same strata again occur dipping 10° to the north, resting on vertical slates that strike east and west, which form also the intervening mountain slope.

The nearest seam of coal on the plateau to Westport, of sufficient thickness to be worked, is at an altitude of 1,800 feet, and twelve miles distant in a direct line, and is that which was discovered, in 1861, by Dr. Haast, at Coalbrookdale, one of the sources of the Waimangaroha. The coal appears on both sides of a shallow upland valley as a 10-foot seam that crops out in some of the perpendicular cliffs in a very conspicuous manner. The quantity of coal available for mining at this place was carefully ascertained by the late Mr. Burnett to be about 750,000 tons (Nelson Provincial Government *Gazette*, 1862, p. 77). He proposed a railway by which this coal might be taken to Westport, the dip, at 1,400 feet from the edge of the plateau, to be overcome by an incline with a stationary engine. The cost of this line, which was to be fourteen miles in length, together with other preliminary expenses, he estimated at £100,000. The proposed line was again surveyed and reported upon by Henry Wrigg, Esq., C.E., (Nelson *Gazette*, 1868, p. 159,) and his estimate for a locomotive line, without an incline, to reach Westport in nineteen and three-quarter miles, together with other works which he recommended, was £133,336. Such a large expenditure would be obviously quite out of proportion to the amount of coal that has been proved actually to exist at Coalbrookdale, and within reach of the proposed line; but it was anticipated that the coal would be found distributed more generally throughout the plateau, and especially towards the west, and that five different seams existed in some places, having a total thickness of 38 feet of coal.

I have not, however, been able to satisfy myself of the existence of

more than one important seam in the different parts of the plateau; and, moreover, have ascertained that the coal at Coalbrookdale is confined to a narrow area, not exceeding 40 chains in width, the extension through the plateau to the westward, as I have already stated, being interrupted by the basement rocks reaching the surface.

Towards the brink of the plateau, on the west side of the basement rock, the coal grits again appear, with a dip of 15° to the west; but they only contain, so far as yet ascertained, a thin band of shales, with one 16-inch seam of coal. To ascertain if any coal seam crops out on the seaward face of the plateau, which is exceedingly deep and covered with *debris*, a search was made from the outcrop of this seam, at 1,700 feet altitude, down to the base of the mountain. Four men were employed for a month in making this exploration, by excavating among the *debris* and in the creek beds.

No fresh seam of coal was discovered by this work; but a trench cut in the face of the hill, for 500 feet above the old Bore-hole camp, proved that the 16-inch seam found there is only a repetition of the thin seam exposed on the surface of the plateau.

The result of my examination up to the present time does not, therefore, enable me to recommend any place where boring should be undertaken on the low ground between the base of Mount Rochfort and Westport.

Ngakawau River.

This river is eighteen miles north of Westport, and is a comparatively small stream, taking its rise in the plateau to the north-west of Mount Frederic. It is the only locality where any mining for coal has been carried on in the district, except in the trial workings at Coalbrookdale, and those at the Mokihinui, to which I shall afterwards refer.

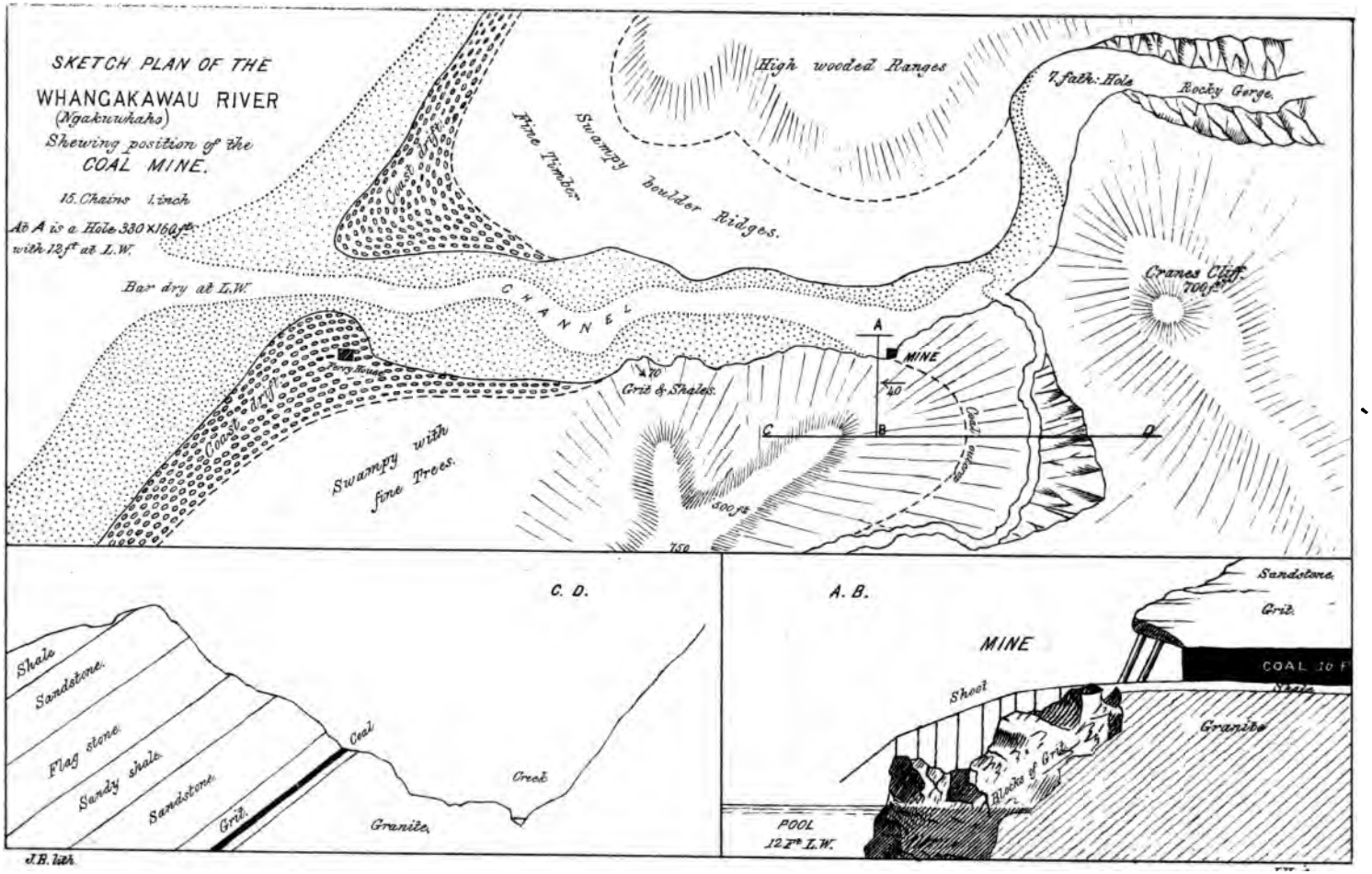
The coal at this place was discovered many years ago, but, until four months since, was neglected on account of the soft friable nature of the seam at the outcrop. The coal mine is 60 chains from the mouth of the river on the south side, at the head of a straight reach which runs east and west from the bar, with an extreme width of five chains, but narrowing very much at the outlet, as shown on the attached plan.

At low water the river is a succession of pools and rapids, from the coal mine to where it runs over the beach; but at high water it is a wide basin, with 8 to 10 feet of water on the entrance. The coal is

within a few feet of the granite, with a sandy shale between. It dips 40° to the west, the strike varying a little from south to south 10° west, as far as can be judged of from the outcrop. The roof is a tough, sandy grit, with mica and carbonaceous markings (20 feet), covered with micaceous flags and thin beds of brown sandstone (60 feet). These beds are followed by gritty sandstones and indurated sandy shales, the above formations forming a ridge that runs parallel with the coast to the south, rising from 300 to 1,000 feet in that direction. About halfway down to the mouth of the river the grits dip for a short distance at 70° to the south-east, but this is probably a local disturbance, perhaps due to the under-cutting of the river.

The excavation that had been made in the coal was only four fathoms in length at the time of my visit (20th May, 1872), on a steep hill side, 30 feet above the water level, and 40 feet back from the brink, as shown in section A. B. A stage and shoot has been erected, with a slope of 1 in 3, and a breastwork in front that will enable it to carry 100 tons of coal in such a manner that it can be discharged at once into a vessel from a height of 20 feet, above a pool 170 feet wide by 5 chains long, in which there is 12 feet depth at low water. There is a pinnacled rock in this pool, which will have to be removed, after doing which, any vessel of a size that can cross the bar will not only have room to swing, but may lie alongside and load during the ebb without taking the ground.

The seam is 16 feet thick, and though very friable and irregularly jointed, with a sooty and rather shaly fracture, it stands well in the face of the drive. There is a "brow" fault about 15 feet from the entrance, through which the surface water leaks, but otherwise the coal is quite dry. Its quality is excellent, and I saw it tested both in a forge and on the open hearth, and nothing better could be desired. It burns freely, with a bright flame and no unpleasant smell. If allowed to remain undisturbed it forms a compact coke, which, with the addition of a little fresh coal, can be entirely consumed, leaving only a small proportion of dull grey ash. The coal can be traced round the point of the spur to the south, the highest point of the outcrop being 100 feet above the water level, and there the coal is a good deal harder than in the mine. The outcrop then descends to a branch stream (Mine Creek), which it crosses about 13 chains (estimated) in a direct line from the mine. The coal has not actually been found where it crosses Mine Creek, as the grits and sandstones there form a very bold but short gorge, which is


SKETCH PLAN OF THE
WHANGAKAWAU RIVER
(Ngakawhaka)
Shewing position of the
COAL MINE.
15 Chains 1 inch
At A is a Hole 330 x 160 ft.
with 12 ft at L.W.
Bar dry at L.W.
CHANNEL
Coast Hill
Pine Timber
Swampy boulder Ridges.
High wooded Ranges
7 fath: Hole
Rocky Gorge.
Cranes Cliff
700 ft
A
MINE
70
40
Grit & Shales.
Coal
C
B
D
Swampy with fine Trees.
300 ft
750
C. D.
Shale
Sandstone.
Flag stone.
Sandy shale.
Sandstone.
Grit.
Coal
Creek
Granite.
A. B.
Sandstone.
Grit.
MINE
COAL 10 F
Shoot
Granite
Blocks of Grit
POOL
12 Fm L.W.
J.B. lith.

occupied by a deep pool, so that the bed of the stream cannot be examined. Below this point, Mine Creek flows over granite to where it joins the Ngakawau, about 100 yards above the mine. Following up this creek the sandstones are seen gradually to pass into sandy clay shale and compact marl of a dark colour, still preserving the same dip as the beds at the mine, namely, 40° to the westward. Half a mile up the creek, in a south-south-west direction, marine fossils, like those in the Cobden limestones, occur in a brown marl-stone. About three-quarters of a mile up, the creek divides into two branches, and in the east branch nothing but the marl-stone is found, but the bed of the west branch is full of large blocks of sandstone and grit, with fragments of coal. On the hill face, east of Mine Creek, the grits are found to rise, still preserving their steep westerly dip, to a height of 800 feet; the outcrop rising at an angle of 15° to 20° to the south-east, as far as could be ascertained in the heavy timber and dense scrub which covers every part of this valley. At 960 feet above the creek the open surface of the plateau is reached, and there the grits and sandstones are found lying flat, but with a general dip to the north and east. No coal has actually been found on this part of the plateau, nor in the outcrop on the face of the hill above described, but, on following the plateau to the south, towards Mount Frederic, there is a 16-foot seam of coal, of equal quality to that at Coalbrookdale, at an altitude of about 1,300 feet. Across the plateau to Coalbrookdale, a distance of about ten miles, the surface is tolerably level, and many outcrops of coal were discovered by Mr. Burnett in this line.

From the level at which the present mine has been opened, up to the outcrop of the seam, I do not estimate more than 80,000 tons will be available, even if no break occurs between the mine and the creek at the back, and about twice as much may be available in the block between the mine level and the water level, so that for shipping this small quantity of coal the river in its present state is quite sufficient. It is easily available, in average weather, for vessels drawing 8 feet, and not over 120 feet in length. By clearing the channel of boulders, and using them for the construction of a pier-head to prevent the surf washing the beach shingle into the river, the bar could no doubt be improved. The existence of granite and good freestone in any quantity and size of blocks required for constructive works, and the circumstance that the only protection required to be provided is against the coastal drift, renders this place particularly favourable for harbour works. The river

brings down no silt or shingle, although liable to good scouring freshets, which is proved by the existence of a 7-fathom hole below the granite gorge, 30 chains above the coal mine. If the coal can be traced from the present mine into the plateau, some harbour works should be undertaken, but even if this extension of coal is not proved, I am inclined to think that this would be a better place from which to work the high-level coal on the plateau than any other which has been suggested. A granite spur from the plateau extends from the east to the head of the reach above the coal mine, and there forms a conical bluff, about 600 feet high (Crane's Cliff), which is steep towards the water, and might be turned to account for lowering the coal to the vessels, from a level that could be reached by an easy tramway from the plateau above.

The arguments in favour of using this river to export the coal from the field under consideration, are,—

1. The low altitude of the plateau at this point—900 feet.

2. The strong probability that the coal will continue and may be worked from the sea level to that of the plateau, by an incline on the east side of Mine Creek.

3. That the coal can be brought along an easy spur from part of the plateau where the best seams exist, to the top of Crane's Cliff, and from there lowered with a self-acting apparatus.

The question then remains whether it would be better to improve the harbour at this place, or to construct a railway to Westport; which is a matter upon which an engineer's opinion should be obtained. It may be pointed out that the facilities for harbour improvements are such that they would probably not exceed the first cost of such a railway, and that, after reaching the Buller, to supply anything like a good large coal trade, very extensive wharfage works would still be required, for which there is no material readily available, the Buller being a large, erratic river, delivering its waters in a low sandy delta, intersected by lagoons and water channels, and liable to sudden and extensive changes at its mouth. The country is, however, very favourable for the construction of a line, if required, north of Westport, as, for most of the distance, it could follow along the foot of the hills to the Waimangaroha, and from there be constructed upon a very perfect shingle terrace, covered with light timber, that runs parallel with the beach. Four or five rivers will have to be crossed, but only one—the Waimangaroha, is of any importance.

The present lessees of the Ngakawau mine will, no doubt, for their own interest, ascertain if the coal can be traced across Mine Creek; and I recommend that, as soon as the season permits, this exploration should be continued for the purpose of tracing the coal into the plateau.

Mokihinui River.

A 6-foot seam of coal, together with some small subordinate seams, occurs about three miles up this river, associated with grits, shales, and sandstones, and dipping conformably under clay marls at a high angle in the same way as at the Ngakawau. At the time of my visit, the river was too much flooded to admit of my examining the section clearly, but Mr. Burnett reported that only a very small portion of this seam is available without sinking and pumping, and that, from its relative position to the bed of the river, very powerful machinery would be required for the latter purpose. The samples of coal I obtained from this place appeared to me of rather inferior quality, but Mr. Burnett states, from an inspection of several tons that were sent to Nelson in 1863, that it burns freely and is very bituminous.

The Mokihinui is a river of considerable size, generally with 10 or 12 feet on the bar, but is liable to excessive floods, which come down with great suddenness, while there is no sheltered place where even a small vessel can bring up within the river so as to be out of the full force of the current.

REPORT ON THE COAL DEPOSITS OF THE ASHBURTON DISTRICT, PROVINCE OF CANTERBURY.

BY JULIUS HAAST, Ph.D., F.R.S.

12th June, 1872.

During the course of last summer I was instructed to examine the Ashburton District, in continuation of my researches into the existence and extent of coal fields in this province, and in the following pages I beg to offer a *résumé* of the main results of that examination, leaving its scientific portion to my more extended geological report.

Although the geological features of the country resemble in many respects those of the Malvern Hills, this resemblance is principally confined to the existence of older rocks, palæozoic sedimentary beds, and melaphyres and quartzitic porphyries,—the absence of the whole series

beginning with the porphyry conglomerates, and including the seams of brown coal, saurian and other fossiliferous beds, up to the green-sands, being very striking.

This non-occurrence of beds so well developed at no great distance is very important in more than one respect, notwithstanding that their place is being taken by younger beds of a somewhat similar nature, with seams of brown coal at their base. This difference would not be so remarkable if a greater distance were to separate both localities from each other, or if a mountain chain of great height between them would have offered an opportunity for the formation of different beds in character or age on both sides; however, both series of beds are situated along the eastern side of the great longitudinal chain, and there are at least at first sight no sufficient reasons to account for this dissimilarity.

Beginning with the oldest beds in the district, the palæozoic sedimentary strata, of which the higher ranges are exclusively composed, we observe also here, that their lowest visible portion consists principally of conglomerates, shales, and coarse sandstones, and of which, in my report on the geology of the Malvern Hills, I have given the principal features. These beds are in some localities replete with the impressions of ferns, of which some are identical with those accompanying the numerous seams of coal opened up in the colony of New South Wales.

I have been able to follow these beds all the way from the Malvern Hills to the banks of the Rangitata, but unfortunately found them devoid of regular coal seams; the existence in many localities of small seams of black carbonaceous shales, or the bark of trees converted into a fine glance coal, making this search after workable coal still more tantalising.

We, therefore, are compelled to assume that during the formation of these very extensive strata, covering the greatest portion of this part of New Zealand, and which have been folded up and denuded in a remarkable manner, the necessary conditions favourable for the formation of seams of coal did not exist.

In another locality, in Mount Potts, on the banks of the Upper Rangitata, these lower beds also appear well exposed in deep gorges, cut by mountain torrents, overlaid by the same sequence of rocks as the fern beds of the Clent Hills; but they contain numerous marine exuviæ, identical or closely allied to Australian forms of older Carboniferous or younger Devonian age, thus offering additional evidence of the age of

the Clent Hill series, as both beds, the fern and shell beds, alternate with each other in New South Wales.

This whole series of older sedimentary strata is, as in the Malvern Hills, overlaid in the district under review by igneous rocks, having been deposited in a semicircular form stretching from the south-eastern corner of Mount Winterslow, across the valley of the Stour, and after forming the very summit of the Clent Hills across the valleys of the Southern or main Ashburton and of the Northern Hinds to the isolated little range between the latter and the Southern Hinds, called the Gawlor Downs.

The relations of these melaphyres, the oldest basic rocks, as well as those of the next series, the acitic or quartzitic porphyries, which in many localities, principally in the north-eastern corner, overlie them, are well exposed in a considerable number of sections. In several localities, however, the latter repose directly upon the older sedimentary rocks, and offer us at the same time sufficient evidence from which we can judge of their age and mode of deposition. One of these localities is on the flanks of Mount Somers, which is principally composed of quartzitic porphyries, and the pitchstones associated with them, and where a small range called Cox Hills runs from its south-eastern end in a southerly direction towards the Southern Ashburton. In the deep gullies of these hills, and principally in Petrifying Gully, splendid sections are opened to our examination; here, above green sands and quartzose sands which overlie directly the sedimentary palæozoic rocks, follow shales with dicotyledonous leaves, and a seam of coal about three feet thick with a dip of 46°, and consisting at the outcrop of an inferior brown coal showing woody structure.

The overlying shales and clays gradually change into porcelain jasper, and are covered by a great thickness of pitchstone-agglomerates, containing pieces from one inch to ten feet in diameter, and which in its turn is again overlaid by pitchstones and quartzitic porphyries, which latter form the great mass of Mount Somers, rising about 3,000 feet above the brown-coal series below them.

A similar seam of inferior brown coal exists in Woolshed Creek, which latter has cut a deep and magnificent gorge on the western slopes of Mount Somers, exposing the porphyritic streams for a thickness of more than 1,000 feet, the whole confirming the observations made regarding the gorge of the Rakaia as to the character of the beds underlying the quartzitic porphyries. (See Malvern Hills Report, page 79, Geological Report, 1871.)

I pointed out already that the porphyry conglomerates, the brown-coal bearing and saurian beds of the Malvern Hills, were missing; their place being taken by a younger formation and of the age of the Curiosity-shop beds, and with which, as far I could observe, no seams of brown coal of any consequence are associated.

There are, however, several other localities where we meet with workable seams, being associated with shales, ironstones, and quartzose sands, but in which I failed to obtain any fossils from which their age might be ascertained. This series might possibly be of the age of some of the coal seams of the Malvern Hills. Several of these seams are situated in such positions that it would be difficult to work them at present with advantage, whilst others are easily accessible and are already worked.

The fact that there is a great deal of timber in the district under review has hitherto prevented the general use of coal in the neighbourhood for household and other technical purposes, but I have no doubt that in years to come some of these seams will offer a good field for industrial enterprise.

The principal locality is situated near the junction of the River Stour with the Ashburton, where in Coal Gully a seam of 14 feet thickness, dipping 8° towards E.S.E., and of which the lower portion of 8 feet is extracted in an adit of proper construction, has been worked for the last eight years. The lessee of the mine is selling only about 150 tons in the year, at about £1 per ton at the pit's mouth. It is a fine pitch coal with smaller layers of glance coal interstratified, possesses considerable hardness with conchoidal fracture, and is of the same quality as the average brown coals of the Malvern Hills.

The principal seam reposes upon porphyry tufas, is covered by shales with smaller seams of brown coal and sandy clay marls, the whole overlaid by post-pliocene alluvium. On the opposite side, and on the southern bank of the River Ashburton, I observed in the banks of a small creek two other seams about 4 and 5 feet thick, which I partially opened up, belonging to the same formation; and near the banks of the River Stour in Alexander Creek, shales and irregular deposits of coal are also met with; without doubt a portion of the same field, although the seams of coal are there irregular and of inconsiderable thickness.

Extent.

It appears from the geological configuration of this country that a

range consisting of quartziferous porphyries stretched, before the deposition of the coal seams, across the present valley of the Ashburton about a mile below the present junction of the Stour, and that thus behind this barrier a somewhat triangular basin existed, about two miles long, and in its largest diameter one mile and a half broad, in which the coal-bearing strata were formed.

Only in a few localities on the sides of the hills these beds have been preserved from the destructive agency of the post-pliocene glaciers, so that they can be worked level free; however, they may nevertheless exist in other spots which are at present covered by post pliocene-alluvium.

The seam in Coal Gully is worked level free, and will be found to extend over 20 acres, so that there are at least 100,000 tons of coal available. The beds on the opposite side of the River Ashburton, from which coal can be obtained also level free, are of smaller extent, but still of sufficient size to be opened and worked with profit.

We have as yet no data from which we could ascertain if the seams in this basin extend to the centre of the valley—if they gradually thicken or diminish—or even if they are confined to the edges of the basin only; but, judging from other localities in this Province which present similar features, we may assume with some degree of confidence that they will be found to stretch across the valley covered by post-pliocene alluvium, and to be reached only by pits.

A second locality where brown coal of excellent quality is exposed is situated on the western slopes of the Clent Hills, where a seam of 28 feet 6 inches in thickness, divided only by small shaly bands, stands at an angle of 63° dipping towards E.S.E., or towards the range.

Except the cast of a cyrena in some clay marls, I did not observe any fossils associated with these beds, so that also in this case we have no data to compare their age with that of other brown-coal measures in New Zealand.

These beds appear to be only portions of a larger formation, which has generally been destroyed by the enormous ice-plough, in post-pliocene times so effectually at work in the outrunning ranges of the Southern Alps. However, as on the other side of the broad valley on the banks of the River Cameron, small seams of brown coal also appear below the morainic accumulations, we may not hope in vain that also in this large opening in the ranges round Lake Heron extensive deposits of brown coal may lie hidden which will be of considerable use in years to come.

Finally, in the bight which is formed by the junction of the Cox range with Mount Somers, a series of seams of lignite occurs, probably being portions of beds of larger dimensions, which in other localities in that district are either hidden below post-pliocene and recent alluvium, or removed by glacier or fluviatile action. This series, which has an average dip of 14° towards N.N.W., reposes here upon quartziferous porphyries, and begins with beds of porphyry, tufa, and fireclays, covered by a succession of shales alternating with seams of coal 2 to 5 feet thick; the coal consisting of distinct layers of earthy brown coal and lignite, the latter exhibiting quite clearly the woody structure.

As all these beds do not apparently enclose any fossils, it will be difficult to fix at present their exact age, although I have no doubt that they belong to the lowest portion of our tertiary series, called the Curiosity-shop beds.

The next beds under review, which by their hardness have resisted well the action of glacier agency, or of the huge torrents issuing from the enormous ice-masses once filling the upper portion of the country, consist of a series of sands, shell-sandstone, palagonite tufa, calcareous and tufaceous sandstones and limestones, forming often bold and picturesque cliffs. They contain a great variety of shells and other exuviæ, all indicating that they belong to the above-mentioned tertiary Curiosity-shop series, the principal fossils being *Pecten Hochstetteri*, *Turritella gigantea*, *Pectunculus laticostatus*, and *Waldheimia*. They do not contain any workable seams of brown coal, but abound in fine quartzose sands, building stones, and limestones.

Summing up the results obtained, the examination of the Clent Hills district has proved the existence of workable seams of good brown coal, and of which those in the Ashburton-Stour Basin are easily accessible, of fireclays, white quartzose sands, limestones, and building stones, and which will in years to come be of considerable value to the adjoining districts.

FURTHER REPORT ON THE MALVERN HILL COAL, CANTERBURY.

BY DR. HECTOR, F.R.S.

6th July, 1872.

M. Hill has lately succeeded in reaching a 7-foot seam of coal, at a depth of 106 feet, in the shaft which he has sunk on his property in the

Malvern Hills, of which Dr. Haast has forwarded a sample for analysis, together with a section of the shaft, which has an important bearing on his previous report. (Geological Reports, 1871, p. 135.) The sample proves to be a common brown coal, not a pitch coal, and is exactly similar to that which exists in the church reserve farther down the Selwyn River, and to the coal which has been for many years mined on the Hawkins River by Mr. Jebson. The chief interest in this discovery is the change in the value of the coal which it discloses, from that previously found in the same close vicinity, which was of very superior quality.

The section of the strata passed through in the shaft furnished by Dr. Haast is as follows :—

Depth to lava stream,—	Ft.	In.
Clay and shales	58	0
Dolerite stream	26	0
Shales	8	0
Coal, very much altered	0	8
Shale	6	0
A. Coal, less altered	1	6
Shales	3	0
B. Coal, fine pitchstone	1	0
Shale	2	6
C. Seam of pitch coal	7	0
	113	8

I append for comparison, along with the analysis of the last specimen sent, the composition of the coal from two seams cut in a drive two chains distant, and which I suppose to correspond with the seams marked A and B in Dr. Haast's section. This comparison clearly shows that no rule can be applied in this district as an indication of the value of the coal founded on the age of the formation in which it occurs, or on the depth at which the seam is struck; and that the improvement in quality observed in some seams, is entirely due to the manner in which they have been affected by volcanic rocks subsequent to their deposition.

	A.	B.	C.
Fixed carbon	67·49	53·30	41·22
Gas and oil	17·89	33·97	31·69
Water	2·12	9·98	20·74
Ash	12·50	2·75	6·35
	100·00	100·00	100·00

A is a compact, lustrous coal, quite black, and approaching an anthracite in appearance, and is in contact with volcanic rock.

B is a massive and less friable coal, and of rather duller lustre, except where traversed by laminæ of jet, and was separated by about 8 feet of shales from the overlying volcanic rock.

C, the coal now sent from the newly discovered 7-foot seam, is a dull brown coal, without lustre, and cracks into fragments on exposure to dry air.

The comparative value, for steam purposes, of these coals is as follows:—

A. 8·77 ... *B*. 6·92 ... *C*. 4·83

These figures representing the pounds of water which a pound of each coal will evaporate.

The upper seams have, therefore, undergone a process like that of coking; the lowest seam, which is 23 feet below the lava, not having been influenced by it. I therefore anticipate that only portions of the coal in the Upper Selwyn Valley will be found to be of superior quality, and that a large extent of the seams still remains unaltered; so that the result of Mr. Hill's exploration requires a material diminution of the estimated amount of steam coal in this area, which was stated in the previous report by Dr. Haast, although it is at the same time satisfactory to find that the brown coal has considerable extent.

REPORT ON THE SHAG POINT COAL FIELDS, OTAGO.

BY JULIUS HAAST, PH.D. F.R.S.

12th June, 1872.

DURING the past autumn, at the request of the Director of the Geological Survey, I paid a visit to the Shag Point district, in order to report on the present state of the coal mine which is worked there, and give my opinion on the value of the coal measures, their relations to the limonitic sandstones overlying them unconformably, and with which, in other localities, brown-coal series are associated; also to institute a comparison between them and beds of similar character in other parts of the Colony with which I am acquainted. I found the beds in question not only of great scientific interest to the geologist, but also of considerable practical value to the Colony, as the following notes, containing some of the principal results of that examination, will readily show.

The Shag Point coal measures are the upper portion of a littoral formation of great thickness, consisting mostly of conglomerates, gritty sandstones, and shales, with seams of pitch coal, deposited on the slopes of the Horse Ranges, running at a distance of about three miles inland, parallel with the coast. This series has a thickness of several thousand feet, and is divided into two portions, of which the largest one is situated inland, being about seven miles long and on the average two miles broad, containing the older portions of the beds, and not reaching anywhere the sea coast.

The other and smaller portion, containing the uppermost beds of the whole series is separated from the lower portions by tertiary rocks of younger age, which run for a distance of about one mile from the eastern flanks of Mount Ivitia, along the northern banks of the Shag River to the western flanks of Mount Vulcan, capping that hill on its northern portion to the sea coast. This second portion is about one mile and a half long, and a quarter of a mile broad, and contains the principal coal seams of the whole series.

The lowest beds of the whole formation consist of subangular pieces of micaceous schists, often much decomposed, with occasional beds of small seams of coal six to fifteen inches thick, of ironstones and ferruginous sandstones. Ascending higher in the series, the conglomerate, which in its lowest portion had more the character of local *debris* cemented together, becomes gradually more rounded, and consists now, often almost entirely, of well-rolled pebbles of quartz.

After a thickness of several hundred feet, this conglomerate, which hitherto had almost exclusively formed the ranges, is overlaid by a series of thick-bedded sandstones and shales of a total thickness of about 150 feet, the latter containing a great number of small seams of excellent brown coal, but unfortunately too thin for any practical purpose, the largest one being only about twelve inches thick.

This portion of the formation is well visible, as the strata where they are cut through by the deep ravines descending from the Horse Ranges have given rise to enormous slips, so that the character of the beds is well exposed. I was enabled to follow these strata from the valley of the Shag River to the ranges above Trotter's Creek, where they are hidden below tertiary rocks.

Still advancing higher in the series, the beds of Mount Ivitia are reached, where we meet, between thick beds of conglomerate, layers of white quartzose sands, often very incoherent, and shales, and amongst

the latter a seam of fine pitch coal, with smaller layers of glance coal interstratified, and of a thickness of 3 feet 9 inches; however, as the dip of these beds, which in the lower portion is only inconsiderable, gradually becoming steeper, has now already reached 64°, this seam will therefore be of little use for the extraction of fuel.

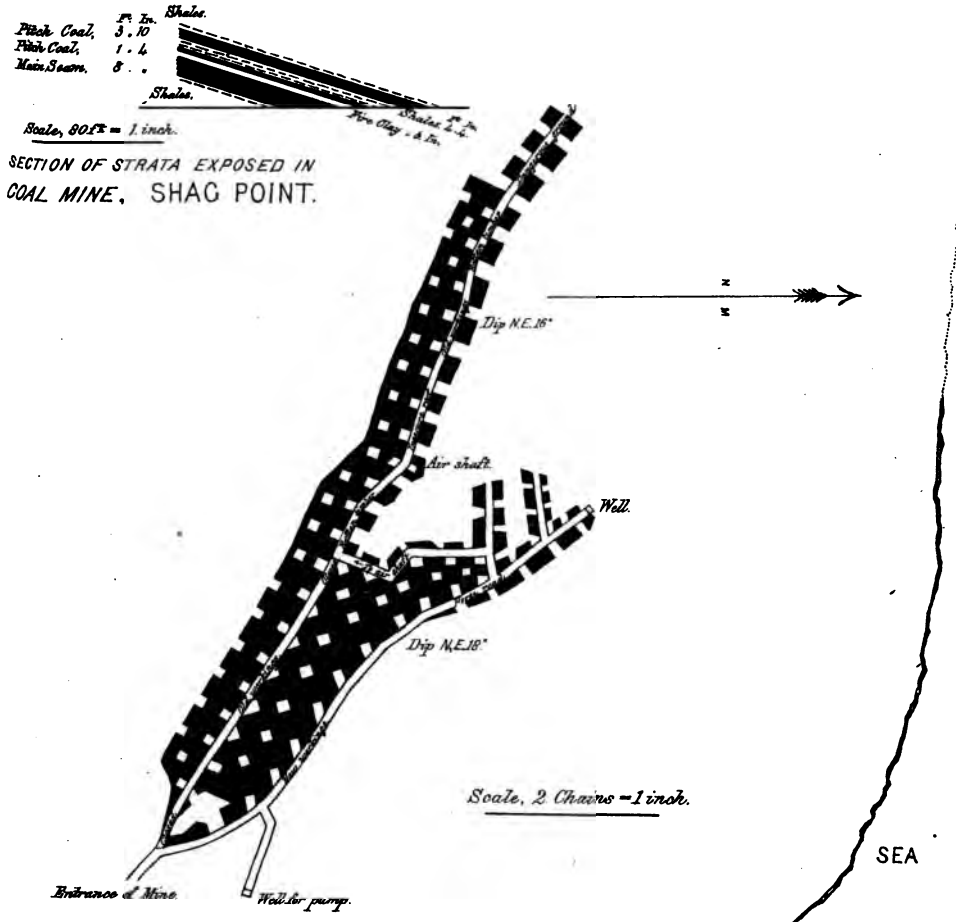
The smaller portion of the series, separated from the larger one by a belt of tertiary rocks, consists first of thick beds of conglomerates, mostly well-rounded pebbles of quartz, overlaid by shales and thick-bedded coarse sandstones, still standing at a high angle (62°); continuing to follow them down the Shag River for half a mile, the strata which hitherto had principally again been conglomerates becomes gradually less steep, dipping 49°, and consists now of shales with small seams of coal and bands of clay-ironstone, containing the same fossil plants as the shales in the coal mine at the Boat Harbour.

Before reaching the mouth of the river, the dip of the strata has diminished to 31°, and we meet here, between the conglomerates, quite a series of coal seams, often interstratified with them, and of which five workable seams of a thickness of at least 20 feet are exposed. These latter beds are covered by sandstones and conglomerates, by which the precipitous sea coast near the mouth of the river is formed.

In following the coast in a northerly direction, we observe that the strata have an anticlinal arrangement, the coal seams having been greatly destroyed by slips and denudations, the beds immediately below them forming the coast line until we reach the so-called Boat-Harbour, where the larger seams appear again just above high water mark, covered unconformably by tertiary beds. It is here where years ago a coal mine for the extraction of an excellent brown coal (pitch coal) was opened, which at present is worked by Mr. J. C. Rowley, of Heathfields, who raises about 250 tons per month, sold at 15s. per ton at the pit's mouth.

The following beds have been exposed in the coal mine in a descending order:—

Shales.	Ft.	In.	
Pitch Coal	3	10	Dip, 16° towards N.E.
Shales	4	4	
Pitch Coal	1	4	
Fireclay	0	6	
Main Seam Pitch Coal (at present worked)	8	0	
Shale	0	0	



UNDERGROUND SURVEY

On April 6, 7, and 9, 1872,

OF THE

SHAG POINT COAL MINE, OTAGO,

BY

JULIUS HAAST, PH. D., F.R.S.

The black coloured portion shows where the 8 feet seam is worked out. Old workings run parallel with high water-mark. New workings have a fall 37 degrees in the main drive to well.

It will be seen from this list that there is at least one more workable seam which hitherto has not been worked, and which is situated above the seam at present mined.

The coal mine is situated mostly below high water mark, and is worked on the Scotch Pillar and Stall system, 8 feet being left and 14 feet taken. It is approached by a main drive (horse road) 7 feet high and 6 feet wide, dipping about 3°; the water being collected at the end in a well, and brought out in an iron chest containing about half a ton, on the average, eleven times a day. This new or main drive runs 7 chains 12 links to this well, whilst some of the older or high-level drives which are connected with the former by well-secured cross drives have been advanced nearly 9 chains. (See Plan.)

The whole portion of the new mine is all in good working order, well secured, and ventilated by an air shaft 5 chains from the entrance of the mine. In the present mine there are thus two seams available of 4 and 8 feet, together 12 feet; whilst it appears, from my examinations in other localities, that besides minor ones, another seam of about 7 feet will be found below these two seams, thus offering about 19 feet of coal in three workable seams; but taking only 15 feet of coal as available, and over an area of seventy acres, which, as I shall show in my final report, is only a moderate estimate, this would give us about 1,600,000 tons of coal, which, in order to allow for possible disturbances or other causes by which this quantity of coal might be diminished, reduced by more than one-third, would still leave us at least one million of tons of workable coal.

The Age.

This formation, which in its characteristic feature resembles greatly the conglomerate beds of the Malvern Hills, seems to be, if not altogether devoid of the remains of animal life, exceedingly poor in them, as I could not find the least traces, notwithstanding the most careful search; but the shales and ironstones, principally those in the uppermost portions of the whole series, are sometimes full of the exuviæ of plants, consisting mostly of dicotyledonous leaves of ferns and coniferæ. Of the latter, the principal specimens, consisting of leaves and twigs, belong to a pine, without doubt closely allied to *Dammara*, and which has also been found in the septaria of the Waipara, thus indicating that both formations, in other respects so dissimilar, belong to the same geological horizon.

This formation is overlaid unconformably by a series of conglomerates and ferruginous (limonitic) sandstones, which in this part of the country do (as far as I could ascertain) not contain any workable coal seams; whilst more to the north, in the Otepopo district, and lying directly upon the micaceous schists, a seam of brown coal of fair quality occurs, about 5 feet thick, and which is at present worked. Owing to the fact that this coal mine lies about 800 feet above the level of the sea, only accessible by a steep road, and the beds of limited extent only, these deposits are not of practical value at present, except for local purposes.

I may also here observe that in several localities the lowest beds of this younger or limonitic sandstone formation, upon which the Moeraki Septaria bed reposes, the former consisting of a quartz conglomerate, with a very ferruginous matrix, is so auriferous near the contact with the underlying beds, that in some places adits have been driven into the hill side for the extraction of the rock, the stuff thus gained, being broken up with hammers and washed, giving fair wages to the miner.

Practical Suggestions.

The great drawback to the development of the Shag Point Mine, to take the coal seawards, is the existence of a rock midway in the entrance of the small cove adjoining the mine, generally called the Boat Harbour. If it were found to be practicable to have this rock removed, coasting vessels of fair size could come close alongside the mine, and be loaded from the coal trucks. Hitherto vessels loading here have to stand outside, and a boat, carrying several tons of coal in bags has to go backwards and forwards in order to load them, by which process, besides the loss of time, the price of the coal is materially raised.

Moreover, the present possessor of the mine—Mr. J. C. Rowley—proposes, if the rock in question were removed, to run a steamer of about 50 tons burthen to and from Dunedin, and sell the coal for about 15s. per ton in that city, by which a great boon would be conferred on the inhabitants of that portion of New Zealand, and at the same time make the establishment of many industries possible which hitherto, owing to the high price of coal, could not be begun. Such a steamer, trading regularly between Shag Point, Boat Harbour, and Dunedin, would also transport passengers and goods in both directions, and thus foster commerce and agriculture.

If, therefore, the locality were examined by a Marine Engineer, in order to see if the rock could easily be removed without destroying the value of that small harbour, a great boon would be conferred upon the district.

However, there is still another way of bringing the Shag Point coal into more universal use, by constructing a tramway or light railway to the Moeraki Harbour, and shipping the coal from thence; and by connecting that rail or tramway with another line running through the saddle between Mount Ivitai and Mount Vulcan as far as Palmerston, the fertile and rising district surrounding that township would be brought into easy and regular communication with Moeraki, a harbour which presents so many facilities for shipping.

REPORT ON THE COAL SEAMS AT WANGAROA AND MONGONUI, AUCKLAND.

BY DR. HECTOR, F.R.S.

4th July, 1872.

Wangaroa Harbour.

This is a deep, land-locked harbour, surrounded by bold, almost precipitous, cliffs of volcanic rock, trachytes, and trachytic agglomerate. These rocks rest on tufaceous sandstones and conglomerates, with beds of fine smoothed-grained mudstone, containing fossil leaves of a very recent-looking character, comprising dicotyledonous plants and ferns, among the latter being a *Pteris* that closely resembles the common bracken, still growing on the hills, These plant-beds are well displayed in the cliffs, at the base of St. Peter's, a dome-shaped hill 500 feet high, on the north side of the harbour, and opposite to which is a similarly formed hill called St. Paul's. The above strata have a general dip at a low angle E. and N.E.

At the head of the harbour the cliffs recede, and there is a large extent of low land, with mud flats covered with mangroves. In the low promontory round this part of the harbour, a totally different formation is exposed, consisting of green sandstones, grit, and sandy shales, containing mica, vegetable remains, and small irregular seams of coal of fair quality. The thickest seam is only 2 feet, and cannot be traced far. It is exposed in a mud flat beneath the high water mark, and dips to N.W. at 27°. On the adjacent shore, a hole was sunk 12 feet from the

line of the outcrop, and cut the coal again at a depth of 6 feet; but three other shafts, 9 feet, 15 feet, and 27 feet, in good situations, failed to strike the coal, only alum shales, with carbonaceous markings, being found. Over these beds are sandy clays, with nodules of calcareous ironstone, containing a few casts of fossil shells. In the Kaiou Creek, which enters the harbour from the south, a tough gray clay marl, with irregular ferruginous partings, is to be seen in the road cuttings for several miles, and is probably an upper member of this older series of rocks, which I suppose to be the equivalent of the coal formation at Kawa Kawa and Whangarei.

Subsequently to my visit, a thick coal seam was found, associated with green sandstone, in the upper part of this valley, but I am not aware of the precise locality. Specimens were, however, forwarded for analysis by Mr. H. Williams. The external appearance of this coal, and especially its bright, lustrous fracture, resembles that of the Grey River coal, but from its composition it is much inferior to either that coal or the Kawa Kawa coal in useful qualities. It is hydrous pitch coal, compact, with very irregular cleavage, and a dark brown powder and glistening streak. It burns freely, containing 84·60 per cent. of combustible matter, the rest being water and a very small quantity of ash. It has not been received in sufficient quantity to test practically its efficiency as a steam generator, but its theoretical evaporating power is 6·5, that of the Kawa Kawa coal being 6·8, while that of the Newcastle coal and the Grey River coal is about 8·0. Its specific gravity, upon which depends the comparative space it will occupy in bunkers of a steamer, is quite as good as that of the Kawa Kawa coal, one ton occupying 1·018 cubic yards. It is a non-caking coal, and in this respect, and in the rather large percentage of water it contains, it resembles common brown coal. It yields half its weight of bright, glistening coke, with a fair amount of gas, but rather less in quantity and of feebler illuminating power than the Kawa Kawa coal, to which it is however superior in respect to the small quantity of sulphur it contains.

Excepting in the low ground at the head of the Wangaroa Harbour and in the tributary valleys, the coal series was not observed, the rest of the district consisting of broken ridges, and shallow swampy valleys in the upper volcanic rocks; and no formation was detected between this place and Mongonui, except the volcanic and palæozoic rocks, which form the framework of the district, and on the hills give rise to a stiff clay soil, generally known as Kauri land.

Mongonui.

The rocks round Mongonui Harbour belong partly to this formation and in part to the volcanic series; but on crossing to the west several interesting formations are exposed along the coast, some containing carbonaceous beds.

Greenstone slates extend for one-third of a mile in this direction, and are succeeded by a tertiary deposit of brown, yellow, and dark blue clays covered with sandstone, passing in places into a pebble conglomerate. In Cooper's Bay, at the level of the beach, the lower beds of the formation, which is 200 feet thick, were found to contain fossil leaves similar to those now existing, and fruits like that of the mangrove; also masses of lignite, but no defined beds.

In one place, the lignite has at some time or other been on fire, and parts of it converted into a bituminous mineral resembling very much a mineral obtained on the Chatham Islands, that has been formed under similar circumstances.

The section of the formation which extends across Cooper's Bay and for a few miles inland on the tops of the hills is as follows:—

	Feet.
White indurated clay	30
Sandstone	20
Conglomerate	20
Sandy clay	40
Blue clay with ironstone bands	30
Sandy clay with carbonaceous markings and lignite layers	20
Lignite	4 to 6
Gray laminated clay	8
Conglomerate	20
Slates	

This formation is of comparatively recent origin, and cannot be expected to yield any valuable mineral fuel; but five miles to the westward an older series is exposed, which appears to belong to the coal-bearing formation of the Northern District. On the west side of the Autere River, gray micaceous sandstones in thin flaggy beds occur, with plant-remains overlaid by pebble conglomerate and clay shales, which inland pass into impure limestones.

No coal seams were observed in the lower part of the series, where they might be expected; but in 1865 I received a specimen of

bituminous or oil shale from the Rev. Richard Taylor, which he stated was found at that place. This shale was fully described in a previous report (New Zealand Coal Reports, 1865, p. 45), from which the following is an extract:—

From the composition of this mineral it will be seen that it approaches closely to the famous Torbanehill oil-shale in character, to which it also bears a considerable external resemblance, with the exception of being rather darker and more resinous in lustre. Its properties are as follows: Very coherent, close grained, hard and tough, almost elastic; does not show the slightest indication of laminæ or cleavage planes, having a smooth semi-conchoidal fracture in every direction.

What appears to be the exterior portion of the stratum is of a yellow colour, while the rest is of a dull black colour, and perfectly homogeneous in every part. It is exceedingly difficult to pulverise this mineral, but when a moderately fine powder is obtained, it has a very decided brown or chocolate colour. Its specific gravity is 1·112. It ignites with ease, and bursts into a flame which is sustained for a long time with great vigour. The flame is at first very luminous and bright, but soon becomes long and smoky, and during combustion small oil-bubbles may be seen escaping.

The presence of oil to a large extent among the volatile matters, escaping at comparatively low temperatures, is best observed by heating the substance in a partially closed test-tube to a temperature of 400° Fahr., after previously drying it at 212°. The oil is then seen to condense upon the cooler portion of the tube in considerable quantity; and when finally removed to a cold place, a large portion of the oily matters solidify to a white substance, probably paraffine.

When heated to a dull red heat in a closed crucible till no more gaseous matters are evolved, there remains about 23·00 per cent. of light, non-coherent, cellular, and slightly lustrous coke, and this in the open fire was found to burn readily to a perfectly white ash.

The chemical composition of this coal is as follows:—

Volatile matter	75·20
Carbon in Coke	9·30
Hygroscopic water	1·80
Ash	13·70
Sulphur	Traces.
	100·00

Relative percentage of volatile matter	...	88·99
Relative percentage of fixed carbon ...	...	11·01
		100·00

I have never heard of any other samples of this interesting form of coal being found either in the Mongonui district or in other parts of New Zealand.

At Ohora Harbour, which is twenty miles to the north of Mongonui, the western side of the bluff hill known as Mount Camel is also composed of gray sandstone and shales, in which, though no carbonaceous layers were observed, silicified wood occurs on the surface of the ground.

At Parengarenga and near the North Cape there is another exposure of the same sandstone, shale, and conglomerates, covering an area of several square miles. At the point on the north side of the entrance to the harbour, the formation is seen to dip to the S.S.W. The base of the formation is not seen, the lowest beds being green sandstone, containing seams of semi-bituminous coal of limited extent. From one of these about two tons of coal had been extracted, but there was no deposit of any importance found at the place. The greensands are covered by conglomerates, which form the sea-cliffs, in which are blocks of silicified wood of a black colour, and also particles of coal.

The harbour is bounded by terrace flats and low hills, in which, and in the sea-cliffs to the north, the following section was observed :—

1. At base, greensands with ferruginous bands, showing in the summit of an anticline that runs W.N.W.
2. On this, towards the west, rest greensands, dip 12° to S.W.—20 feet.
3. Fine-grained conglomerate—20 feet.
4. Green sandstone, with a foot of coal—40 feet.
5. Red sandstone, with pebble beds—40 feet.
6. Greensands, with ironstone nodules, containing kernels of white clay—50 feet.
7. Shale, with masses of coal and conglomerate bands—50 feet.
8. Finely laminated greensand—40 feet.
9. Green sandy shale with flat cement-stones, containing plant impressions, bedding very regular, but the strata are cut by joints lined with calcareous spar and ironstone—80 feet.
10. Conglomerate—10 feet.
11. Nodular sandstone.

Resting unconformably on the above are calcareous shales and marlstones.

Parengarenga Harbour is not suitable for vessels of large size, the depth of water on the bar being only a few feet.

The foregoing notes were made in the course of a general and cursory examination of the district for a few days in January, 1866, and sufficiently prove that there is a considerable development of coal in the district north of the Bay of Islands. I was not successful in getting perfect fossils, and therefore cannot express a decided opinion as to the age of the formation in question; but in the geological map of the district I have placed it provisionally in the same group with the Kawa Kawa coal.

The only recommendation I at present feel able to make is, that the coal up the Kaiou Creek should be opened out and traced on the surface if possible, so that, its true direction being ascertained, it may be sought for at the most convenient place to the deep water. Boring should not be resorted to until it is very clearly established that the coal may be expected to occur in the particular locality selected. This course was previously recommended to the persons locally interested, but I have never heard of the result.

The existence of valuable coal near Mongonui at present rests on the evidence afforded by the occurrence of carbonaceous sandstone near the Autere River, and the single specimen obtained by the Rev. Richard Taylor, as I do not consider that the lignite deposit at Cooper's Beach and close to Mongonui would answer for steamers.

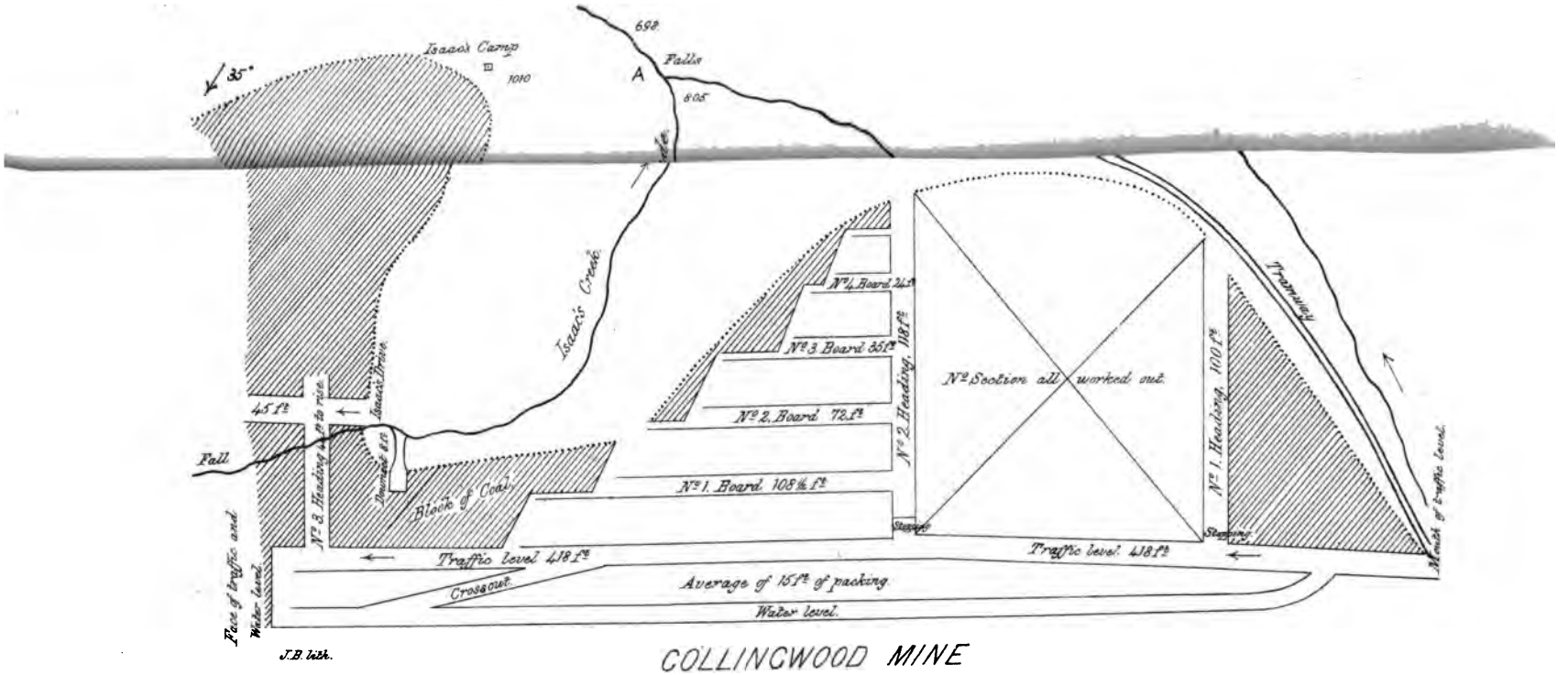
REPORT ON THE COLLINGWOOD MINE, NELSON.

BY DR. HECTOR, F.R.S.

30th June, 1872.

THIS mine is situated in the Pakawau Coal Field, the general characters of which are described in a previous report (Geological Report, 1867, p. 19), made when the coal seam had been only recently discovered, and no mine had been opened. A description of the state of the mine last year was given by Captain Hutton (Geological Reports, 1871, p. 157).

To reach the mine the river is ascended in a boat for half a mile to a point where wharves have been built, and where vessels of small size can load. From this point to the foot of the hills, a distance of one



J.B. lith.

COLLINGWOOD MINE

Workings in upper Seam.

mile and a quarter, a wooden tramway has been laid through a bush flat, a good deal of iron rail being used near the river. The hill is then ascended by an incline at an average angle of 33°, but in parts even steeper, the length of the incline being 1,300 feet, and the vertical rise 600 feet. The rails on the incline are made of wood, the line being double, and there being also a double length of wire rope, which appears rather unnecessary, as the incline is worked with a single drum and powerful break.

From the top of the incline, a side-hill cutting leads up a valley for about a mile to where it strikes the creek at the top of a vertical fall of 107 feet. The coal is here received into the waggons from screens, to which it is sent down from the mine by a steeply-set box shoot, the difference in level between the mine and the screens being 80 feet. Narrow iron tramways are laid down from the different levels in the mine to the shoot.

The mine consists of workings in two seams of coal, which have been opened out at the lowest level at which they can be cut in the bed of the creek, and from there excavated to the outcrop on the brow of the spur for a distance of two chains. The workings extend on the strike of the seams for about five chains, and are then cut off by another branch called Isaac's Creek, the whole of the available coal in the block between the two creeks having now been worked out.

To the north of the present workings there is still a block of untouched coal, from the traffic level, for four chains on the rise to the point on the plan marked Isaac's Camp, which is 1,060 feet above the sea level, and at the top of a vertical precipice that rises 316 feet above the foot of the fall. To get at this coal from the present mine will require the putting in of a drive at a cost of about £150, to pass under the level of the north branch of the creek, at a safe distance, to avoid tapping it.

The above-mentioned works have been constructed by a company chiefly consisting of working shareholders, and I have no hesitation in stating that all the works have hitherto been carried out in a most substantial and yet economical manner, and that they display a very great amount of enterprise. It however appears that no return has hitherto been made on the capital employed, and that the sale of the coal has merely paid working expenses, and it is therefore important that in any fresh extension of the mine a still more economical system of working it should be adopted.

The supply of coal available by the present method of working being almost exhausted, the first step will be to lay open a fresh area of the seams; and the consideration of how this can be most advantageously effected, requires a statement of the geological conditions under which the coal occurs.

In following up the bed of the stream to the foot of the fall, and also along the incline and tramway cutting up the side of the valley, a section of the rocks which underlie the coal measures is obtained. They consist first of clay schist containing mica and a little quartz, the apparent bedding of which dips at 40° to W.S.W., or into the body of the hill. This is probably not the original stratification of the rock, but rather a foliated structure which has been superinduced; for both in the bed of the creek at 300 feet altitude, and in the tramway cutting about 5 chains from the top of the incline, a bed of blue, red, and white crystalline limestone about 80 feet thick occurs, that appears to be more nearly vertical, but is at the same time traversed by thin layers of mica that have a moderate dip to the west. These mica layers are hardly perceptible in fresh fractured surfaces, but, when the limestone has been weathered, they stand out in high relief, and have complicated contortions like those usual in mica schist.

This limestone is an important feature in the geology of the district, as it can be traced along the eastern face of the hills towards Pakawau, and in several places is associated with graphite shale and talcose slate. Red and blue clay schists, containing mica and quartz, then follow, in the bed of the stream, the section along the tramway being obscured by slipped ground.

The coal measures commence in the tram-cutting 5 chains before reaching the shoots, and the junction is also very well marked by a rock parting stained with iron, which crosses the precipice at the vertical fall, about 40 feet from its base, the lower part consisting of brown mica schist, with an apparent dip of 40° to N.W.

1. The lowest bed of the coal measures, resting on the above, is a blue-gray breccia of angular fragments of schist and slate, together with angular and rounded masses of quartz, the surface on which this breccia rests dipping 30° to W. 10° N.—thickness, 35 feet.

2. Conglomerate of well-rolled quartz, quartzite, and crystalline sandstone, cemented with gray sand—20 feet.

3. Gray sandstone that weathers red and contains patches of fine-grained breccia, flakes of slate and quartz—50 feet.

4. Tough brown and green argillaceous sandstone and carbonaceous shales, in thick beds, with layers of grits and coal seams, of which six are known. Average strike, N. 15° W., dip from 25° to W., but getting flatter into the hill—250 feet.

The coal seams already discovered in this part of the formation are as follows, in descending order :—

No. 1. Exposed in face of fall on the north branch above Isaac's Drive—coal, 1 foot.

No. 2. Upper seam, which is worked—coal, 2 feet 5 inches. This seam contains a stone band, of variable thickness, the coal below the band being generally the most regular. About one-third of the stuff excavated from the seam has to be rejected.

No. 3. Lower seam worked—coal, 3 feet. Contains a single stone band, which has shown a tendency to thin out towards the S.W. corner of the workings, being from 6 to 16 inches thick.

No. 4. Cut in the first drive made in Isaac's Creek—coal, 2 feet. Has a 2-inch stone band. In the first creek, north of Isaac's Camp, this seam has 2 feet 8 inches of clear coal.

No. 5. In the creek below the old workings, but so mixed with stone as to make 2½ feet—coal, 1 foot.

No. 6. In the waterfall on Isaac's Creek, beside the shoot, 4 feet thick, but very inferior, not showing more than 6 inches of pure coal. This is the lowest seam, and is about 60 feet from the base of the brown sandstone group.

The remainder of the section to the top of the hill has been very imperfectly observed, on account of the thick bush. At 200 feet above the highest coal seam known I found a light brown micaceous shale, full of the same fossil leaves which are abundant at Pakawau (dicotyledonous leaves, ferns, etc.) ; and at a still greater altitude, the bearing being S. 20° E., hard brown carbonaceous sandstone, also with fossil leaves, N. 10° W., dip 35° to W.

It is thus pretty certain that the greater part of the hill above the mine is composed of the sandstones belonging to the coal measures, but Mr. Marshall, the Manager of the mine, informed me that on the top of the range, about two miles back, there are blocks of sandy limestone of quite a different kind from that cut in the lower part of the hill, and resembling the fossiliferous limestone on the coast at Wanganui Inlet. Four miles W. by N. from the top of the range above the mine, is the House-roof Hill, a sharp-topped cone which I ascended from West

Wanganui Inlet in 1866, and found to be an isolated boss of granite, 1,750 feet high, and surrounded to the height of 1,000 feet by sandstones containing thin coal seams, like the uppermost beds above described. The country between House-roof Hill and the top of the range is a slightly depressed plateau, so that the coal measures must either lie tolerably flat, or have small undulations. This has an important bearing on the future works for developing the coal, which I shall have to discuss, as it affords strong evidence that the coal seams will not continue with the high dip which they have at the outcrop. This is also confirmed by the actual workings in the coal, in which both seams at the outcrop dip at 1 in 3 (or 19°), and in the lowest level at 1 in $3\frac{1}{2}$ (or 16°). The dip is also much steeper where the coal is exposed in the creek north of Isaac's Camp, which is still further to the eastward, for there the same seam dips at 35°, and the strike is changed from N. 10° W., as it is in the mine, to N. 12° E.

Two tunnels were suggested by the late Mr. Burnett (who originally planned out the works for the Company), for the purpose of cutting the coal seam at a lower level than the present workings :—

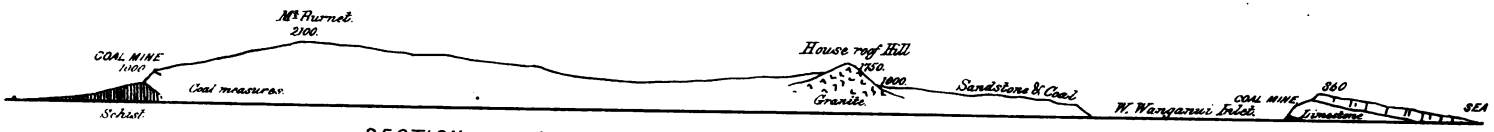
A—From the bottom of the perpendicular fall.

B—From the top of the fall, or nearly the head of the present tramway.

The tunnel selected should be driven at right angles to the strata, and according to the angle of dip would be the length of tunnel required, and their position is shown on the section, which is from rough measurements I made with an aneroid in 1866, and therefore only an approximation.

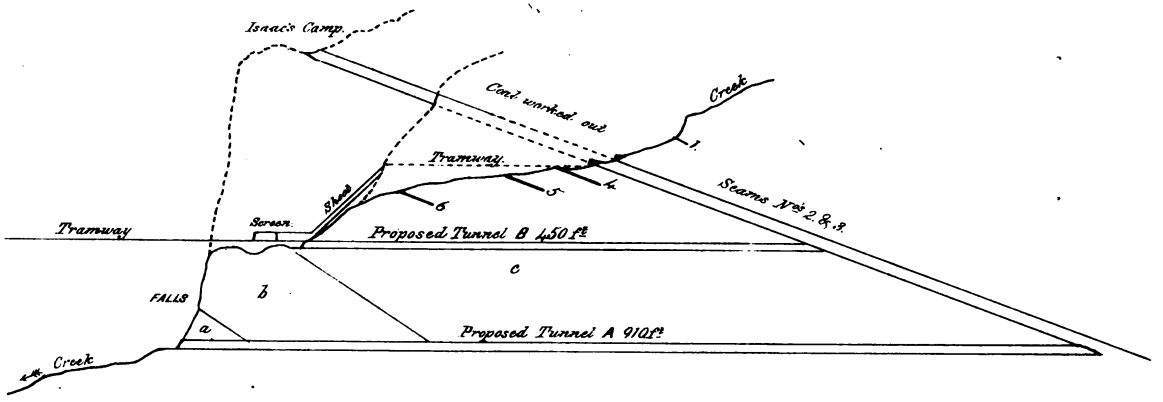
In the case of the lower tunnel A, by taking the dip of the coal at 16°, as observed in the mine, the length to cut seam No. 3, or the lower seam that is worked, would be 970 feet, but if the steeper dip at 25° were taken, about 720 feet. Of this about 100 feet is schist, and 300 feet would be in the breccia, conglomerate, and gray sandstone; after which the lower sandstone with shale partings would be reached, and in this the work would be comparatively easy.

Tunnel B, allowing for the positional advantage it gains by the erosion of the gulley, and calculated on the least dip observed, would have a length of 450 feet, and at the greatest dip a length of 350 feet. In this case the whole of the lower beds would be avoided, and the drives would all be in the upper brown sandstones, or proper coal-bearing beds, and the lowest, or No. 6 seam, should be cut after driving about 130 feet.



SECTION —— AORERE RIVER TO WEST COAST 8. MILES. W. by N.

Section, Vert. & Hor. 3000 ft. to the inch.



SECTION OF PROPOSED TUNNEL (a.) COLLINGWOOD MINE.

a. Schist b. Breccia & Conglomerate. c. Sandstones with Coal.

J.B. lith.

J. HECTOR.

The calculation of the quantity of coal that would be "won" by these drives respectively, may be founded on the experience in the present mine. The total area of the mine is about one acre in extent, from which some 5,000 tons of coal have been obtained, 3,200 tons being the quantity sold by the existing Company, the rest being allowed for former working, waste, and consumption at the works. Rejecting the ground that has been considered unworkable, and taking each seam respectively, we find—

	Tons.
In upper or 2½ feet seam, ground worked $\frac{1}{5}$ acre ...	1,050
In lower or 3 feet seam, ground worked $\frac{3}{4}$ acre ...	4,440
This gives per acre for upper seam	5,000
„ for lower seam	5,550
Total per acre for both seams	10,550
But as more than half of the ground hitherto opened has been too thin to work, deduct say	5,550
Available per acre	5,000

Taking the dip at 20°, the distance, following the seam from the end of tunnel A to the level of the present working, would be 8 chains, and for tunnel B 3½ chains; so that by excavating the coal by levels for a distance of 5 chains each way from the tunnel, the amount of coal obtained would be—

	Tons.
By tunnel A	40,000
„ B	17,500

To this must be added all the coal that can be extracted from the hill spurs between the creeks, which must be a very considerable amount. I have taken five chains as the length of drives each way merely as an illustration, as, if the mine was found to pay, with a proper system of ventilation, the galleries might be extended to a very great distance.

The only data I could obtain for estimating the probable cost of the tunnels are from the cost of a heading in the lower level that was driven for 90 feet in the "dead rock,"—*i.e.*, not in coal. This cost 30s. per foot, and was in the brown gritty sandstone that forms the roof. A main tunnel for carrying the whole traffic of the mine would, however, require to be of much larger size. The excavation of the upper tunnel I should expect to cost less per foot, as it is a shorter distance, and is in better ground.

In order to compare the cost of the two tunnels, I will assume that the upper will cost 50s. and the lower 70s. per foot, in which case the former will require £1,125, and the latter £3,395, or in the proportion of 3 to 1, while the amount of coal won is in the proportion of 2¼ to 1. Or, if the advantage gained by the drive be valued at about 1s. per ton on the coal, it will take 22,000 tons to pay off the cost of the upper tunnel, and 68,000 to pay off the lower.

It is necessary to point out, in the case of the lower tunnel being adopted, an additional expense would be incurred for the remaking of the tramway from the mouth of the tunnel to the incline. How much that would amount to I am unable to say; but as the valley at the level of the fall is narrow and rough, I believe it would be very considerable.

On the other hand, the present tramway and incline, as they stand, will serve for working the mine from the upper tunnel, the only part of the plant now in use which would be rendered useless being the shoot, which is a most objectionable feature in the existing arrangements. But the greatest objection I have to recommending the lower tunnel is founded on the clear indication that the strata dip at a less steep angle as they pass into the hill, and that the distance required to be driven may in that case not only be greatly in excess of the foregoing estimate, but even that the coal may not reach so low as to be cut in the tunnel A.

From the foregoing considerations, I have therefore no doubt that if either tunnel is made, it should be the upper one; and that if mining operations are to be resumed, there is no better plan to be suggested. It may be thought that a good deal of coal should be won by pumping and hauling by an incline from the present workings; but that would add more per ton to the cost of getting the coal out than the expense of the drive, and would not get rid of the shoot, the use of which, by breaking the coal into dross, greatly reduces its value in the market.

The question of whether thin and irregular seams like those in the mine are worth working, should however be considered before this large additional expenditure is entered on. Seams of pure coal under 2½ feet are worked in many countries, and particularly in Belgium, where few thicker seams occur; but they are free from the stone bands which give so much trouble in the Collingwood Mine. The manager, Mr. Marshall, is inclined to think that there is on the whole an improvement in the purity and thickness of the seams as they dip into the hill, and he is

very sanguine that if they were cut at a lower level this would be clearly established, and that it would even pay to work with the present seams if the shoot were done away with, and a greater extent of ground opened, so that more miners could be at work, and thus keep the brakesmen, tramway drivers, and other hands above ground, fully employed.

It is not necessary to allude to the very favourable analyses that have been made of the coal, as there is no doubt of its value for steam, gas, and household purposes; and that it would compete successfully with Newcastle coal on its own merits may be judged from the reports of those persons who have actually tested the coal, and from experiments that were made on the comparative value of this coal for steam and gas purposes by Messrs. J. R. George and J. Kebbell (*Transactions* New Zealand Institute, Vol. IV., p. 146). It is not quite so free from ash as the Grey and Buller coal; on the other hand, not being so tender, it bears carriage better. The area of the coal field, the capabilities of which the successful working of the mine will test and direct practical attention to, is about thirty square miles. The position of Collingwood is most favourable, as it is very little out of the track of the steamers, and at very slight expense wharves might be built into deep water, Cape Farewell Spit affording perfect shelter from all heavy seas.

REPORT ON THE CLUTHA AND GREEN ISLAND COAL FIELDS.

BY DR. HECTOR, F.R.S.

9th July, 1872.

THE following is a short account of two coal fields which will be rendered available by the Otago South Trunk Railway from Dunedin to the Clutha River; much of the information having already been published in papers presented to the Provincial Government of Otago, 1864, and in other official reports.

The coal deposits referred to may be described as in two distinct areas,—

1. The Clutha and Tokomairiro Field.
2. The Green Island and Saddle Hill Field.

The first of these occupies an area of twenty square miles on the East Coast, north of the Clutha River. The formation consists of conglomerates, sandstones, and clay shales, with several seams of coal.

These strata form a range of hills, 700 feet high, between the Kaitangata Lake and the sea coast, and dropping in altitude to the north, again rise and flank the south-east side of the Mount Misery range, which is composed of the upper schistose rocks. The chief coal seams are at the south end of the above area, and a very clear section of this part of the formation is exposed in the sea cliff between the north end of the sand spit of the Clutha River and Coal Point, a distance of nearly three miles.

This cliff bounds a terrace 70 feet above the sea level, and extending for half a mile back to the base of the hills. The coal measures are exposed in the lower 10 to 20 feet of this cliff, and also in the bottom of ravines that intersect the terrace, the upper part of which is composed of horizontally stratified ferruginous sands, clays, and gravel beds, finely laminated and false bedded. No fossils were seen in this deposit, but it contained nodules of impure siliceous ironstone, that yield traces of phosphoric acid. These sand beds, which are probably of the same age as the gold drifts of the interior, rest on a very uneven surface of the coal measures which form the lower part of the cliff, consisting of alternating beds of conglomerate, sandstone, shale, and fire-clay, all containing more or less carbonaceous matter, and having a general dip of 7° to 12° to the East, but at several places faulted, so that for a short distance the dip is in the opposite direction.

The following is an estimate of the thickness of the various beds exposed along the base of the cliff:—

A. Ferruginous sands and clays in horizontal beds, 40 feet to 50 feet thick.

B. Coal measures, dip, E.N.E.

	Feet.
1. Gravel grit	6
2. Sandstone	30
3. Laminated clay, wlth dicotyledonous leaves	30
4. Double fault, filled with clay of a bright blue colour (1 foot wide)	?
5. False-bedded sandstones	10
6. Quartzose gravel	23
7. Coal (a) (Coal Point seam)	20
8. Carbonaceous shale	?
9. Grit	?

(Here the dip changes to S.W., with an obscure fault.)

		Feet.
10.	Clay slate	... 15
11.	Quartz grit	... 2
12.	Brown sandstone	... 10
13.	Impure coal and fine clay	... 10
14.	Soft blue clay, with ironstone septaria ...	... 6
15.	Quartzose grit	...
	(The dip changes to E.S.E.)	
16.	Gravel grit	... 10
17.	Mullock	... 4
18.	Fire-clay	... 4
19.	Shale	... 6
20.	Coal	... 6
21.	Fire-clay	... 3
22.	Gravel, with carbonaceous streaks	... 6
23.	Impure fire-clay	... 4
24.	Finely-laminated sandy clays, with carbonaceous streaks	... 16
25.	Patch of quartzose gravel, with iron pyrites resting on coal (thins to 3 feet against dip)	... 4
26.	Carbonaceous clay	... 10
27.	Sandy clay, with pebbles interspersed ...	... 30
28.	Conglomerate of slate pebbles, irregularly stratified ...	... 6
29.	Grit, coloured bright yellow, with efflorescence ...	... 12
30.	Carbonaceous shale	... 6
31.	COAL	... 5
32.	Carbonaceous clay	... 15
33.	Yellow and gray clay, with gravel beds and carbonaceous shale	... 15
34.	Grit and pebbly conglomerate	... 30
	(A few chains are here obscured by a more recent formation than even the upper sands, consisting of sand and drifted wood passing into lignite.)	
35.	Red clay	... 4
36.	COAL and fire-clay	... 5
37.	Fine pipeclay	... 4
38.	False roof of gravel stone	... 1
39.	COAL (M) (Coal Mine seam)	... 18
40.	Carbonaceous shale	... 3
41.	Pipeclay	... 1

		Feet.
12.	*Gravel stone*, with grit and stems of trees	60
13.	*Coal*	2
14.	*Fire-clay*	1

15. *This rests on a conglomerate of green schist pebbles, smooth and oval, of various sizes, to 6 inches in diameter, cemented by green and gray sand, containing magnetic iron sand and glauconite, which continues to the Spit. Bedding decided to E.S.E., 15°. This conglomerate is cut by veins of calc spar, a few lines in thickness, that pass N. and S. right through pebbles and cement.*

There are, therefore, in the above distance, four seams of clean workable coal exposed in the section, giving a total thickness of 38 feet; but in some cases the same seams are probably repeated by faults.

The coal seams are apparently very regular, and generally have a roof of tough shale. In only a few cases, however, they rest on fire-clay, as more frequently the floor is of fine-grained conglomerate.

The principal seam, marked M, *is 18 feet in thickness, resting on a white pipeclay and roofed by a dull, carbonaceous clay shale. The lower part of this seam is very black and compact, and contains the largest percentage of water and ash. Towards the top of the seam the coal acquires a more laminated character, and the brown, amorphous coal alternates with thin laminæ of jet. No fragments of wood or traces of unaltered tissue can be observed in this coal; but in the shales above, leaves and stems of plants are of frequent occurrence, perfectly fossilised, but in a fragmentary condition.*

The seam marked A *is that which forms Coal Point. Only the upper part is exposed in the cliff, but it is probably 20 feet thick, as it forms a reef which extends to the seaward, and is exposed for several hundred yards at low water. The coal is variable in quality, but, on the whole, is similar to that in the seam at the mine, and might possibly be the same seam repeated.*

Beyond Coal Point there is a change in the formation, on the coast, for a few chains, to blue, laminated clay, with fossil leaves, which are overlaid by gray sandstone. Northward of this only more recent formations are seen; a sandy limestone, with upper tertiary marine shells, occurring at one place five miles from Coal Point.

The first mine in this district was opened in 1858, in the 18-foot seam marked M, *and for some years was vigorously worked, a large*

quantity of coal being extracted at first by a wide irregular drive from the sea beach, but afterwards by an incline from the bottom of a gully, up which the coal was hauled to the level of the terrace, along which an iron tramway was laid for three-fourths of a mile to the Clutha River, to the level of which the coal was again lowered by an incline to the shipping wharf.

In 1864 a seam was opened in a more convenient position close to the river, and two miles north in a straight line from the old mine, and on the west side of the Kaitangata Range. The seams found here appear to correspond with those in the coast section, but the strata dip to the N.W. at 5° to 7°, which indicates that the intervening hill is an anticlinal arch. From the Kaitangata Range the hills drop in altitude to the North, and are less rugged for about six miles to where the conglomerates flank the east side of Mount Misery, and again rise to about 750 feet, resting on the schist rocks. The coal crops out in several gullies in this part of the range, and in the valley of the Tokomairiro an 8-foot seam dipping to the N.E. was worked at an elevation of 600 feet above the sea level. The upper part of this seam, of which about 3,000 tons had been excavated as early as 1862, is soft and of dull brown colour; the lower half of the seam has a resinous lustre, and burns freely. The coal measures can be traced for nine miles north of the Tokomairiro Valley to the mouth of the Akeritu stream, north of which the schist rocks come down to the sea coast.

The Kaitangata hills will be the most convenient place to the railway from which to work this coal field; and with some modification of the furnace bars, I have no doubt that the coal will answer for the use of locomotives.

Fifteen analyses have been made of this coal from various seams, and the theoretical evaporative power obtained from the average of these is 5·34 lbs. of water for each pound of coal used, the highest being the lower part of the Tokomairiro seam, which is 6·09. This coal is of the same value as fuel as the Southland brown coal, although I have seen no specimen that contains so much resin and burns so freely as the coal from the particular seam at Morley Creek. This is, however, an accidental and local peculiarity, that may be absent in one part of the seam and present in another. On the rise cut through by the road and railway south of Tokomairiro, there is a thick seam of inferior brown coal or lignite. This seam was very imperfectly exposed when I last saw it, but appears to be at least 12 feet thick, and to dip at a low angle

to the S.W., being covered by pipeclay and gravel. Although of very great thickness it is of inferieor value as fuel.

Green Island and Saddle Hill Coal Field.

This occupies a large area in the vicinity of Dunedin, in which the coal seams appear along the western boundary, in a line extending from the mouth of the Otokaia Creek for about nine miles, to the valley of the Water of Leith.

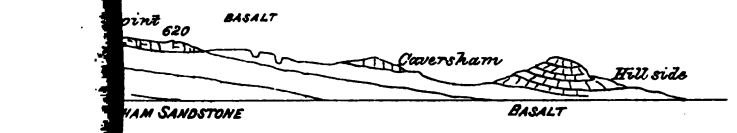
The strata, with the coal, probably have a trough shaped arrangement parallel with the coast, and the lowest beds that can be observed have a prevailing south-easterly dip, and, resting on schist rock, pass beneath the Caversham sandstone, which is a tertiary marine formation, which is again overlaid by the volcanic rocks of the Dunedin basin.

The lowest stratum of the coal measures, as seen on the west side of Saddle Hill, appears to be a thick conglomerate, on which the coal rests, and is worked by drives into the face of the hill at 400 feet above the sea level. There have been extensive landslips in the face of the hill, so that the exact sequence of the strata is not clear; but there are three distinct seams of 8, 4, and 3 feet thick respectively, contained in clay shale, and covered by laminated sands with carbonaceous markings. The upper part of the hill, which is 1,560 feet altitude, is dolerite and basalt, the Caversham sandstone either being very thin, or not represented in the section on the west side. On the eastern slope, towards the sea, however, fossiliferous sandstone occurs over the coal.

From the north end of Saddle Hill the ridge of schist rock increases in altitude to form the Chain Hills, which are crossed by the main south road, and are to be tunnelled for the railway. Several collieries have been in operation since 1862 in this part of the field, close to the eastern boundary of the schist rocks, being the only place in New Zealand where coal mining has been carried on by deep shafts, as in England, all the other mines in the colony being worked either by "free levels" or by "inclines." As at Saddle Hill, there are three principal seams, as shown in the following sections of two of the principal shafts.

At Walton Park Colliery, where the shaft is 130 feet deep, the following strata were passed through:—

	Feet.
Sands, clays, and ferruginous gravels, of which no record was kept, and which belong to a recent tertiary formation ...	65
Bituminous shale and clay, with thin bands of coal	35



POINT 3 miles.

	Feet.
Upper Coal	7
Sandy clay and blind coal	12
Lower Coal	9
Bituminous shale	1
Quartzose sand	2
Gray sandy clay	1½
Coal	2
Micaceous fireclay	4
Sandy clay	15

At Doig's mine, which is situated more to the north, the section is as follows :—

Surface clay, with boulders of volcanic rock, sand, gravel, and other recent formations	80
Resting unconformably on	
Coal	6
Mica shale	3
Coal	2
Grit	3
Coal	2
Mica shale	3
Coal	14

The Green Island coal varies a good deal in quality, but most of it is a lustrous brown coal when first extracted. From the depth of the mines, and the porous nature of the strata, it generally contains a much larger percentage of accidental water than the coal from the Clutha field, so that it cracks and breaks up into small fragments on exposure.

Following the line above indicated to the northward, the next outcrop known is in the Halfway Bush, but the coal there has the character of a bituminous shale, containing a large proportion of ash.

In the Water of Leith fragments of coal have been found which indicate that the seams in that direction have been altered by the igneous rocks. One specimen, stated to have been obtained in the Botanic Garden reserve, has the property of caking, which is quite exceptional even among the altered brown coals. (Lab. Rept., 1871, p. 14.)

No seam has yet been found up the valley of the Water of Leith, so far as I am aware, but several have been recently reported at various points round the harbour. From information furnished me by Mr. Richard Evans, it appears that thin seams have been found, by explora-

tions made under his direction, near Arden's Bay, and more recently coal has been found nearer to Port Chalmers.

The discovery of coal seams in this situation is extremely interesting, and might be of great economic importance, as, if they prove to have been altered by the overlying basaltic rocks in the same way that the brown coals have been altered under similar circumstances at the Malvern Hills in Canterbury, the coal might prove a valuable steam generator.

The average evaporative power of the Green Island and Saddle Hill coal is 5·02 lbs. of steam to each pound of coal, which agrees with the unaltered brown coals of the Malvern Hills; but the altered portions of the same seams at that place have an evaporative power as high as 8 to 9 lbs., or equal to the best English coal.

In an early report on the brown coals, I pointed out that this improvement in the value of the coal by the expulsion of the water and the addition of a small percentage of bitumen, might be effected artificially.

If this process,—a modification of which has recently been brought into use for the supply of locomotives on the Italian railways,—were economically successful, it would render available, for the use of steamers and locomotives, the large deposits of brown coal which are found in nearly every part of New Zealand, and which, in the natural state, are only fit to generate steam for stationary engines.

GENERAL REPORT ON THE COALS OF NEW ZEALAND.

BY DR. HECTOR, F.R.S.

13th July, 1872.

With the view of facilitating reference to the different coal seams in the Colony, which have been reported on by this department the following schedule is arranged according to the Province in which they occur, but from which schedule all analyses of coals not of practical importance have been omitted.

Where several analyses have been made of coals from the same district or locality, they are arranged according to their relative value, obtained by calculating their evaporative power, or the number of lbs. of boiling water which should be evaporated by one lb. of each kind of coal. In making this calculation, the same method has been adopted as

that employed in similar investigations in other countries; and in the case of those coals that contain a large per centage of water, a due allowance has been made for the consumption of heat in the conversion of that water into steam.

The terms applied in the schedule to the different varieties of coal in New Zealand are to be used with the following definite meanings:—

I. HYDROUS. (*Coal containing* 10 *to* 20 *per cent. of permanent water.*)

a. Lignite.—Shows distinct woody structure, laminated, or shows that structure on desiccation; very absorbent of water.

b. Brown Coal. — Rarely shows vegetable structure. Fracture irregular, conchoidal, with incipient lamination; colour, dark brown; lustre, feeble; cracks readily on exposure to the atmosphere, losing 5 to 10 per cent. of water which is not reabsorbed; burns slowly; contains resin in large masses.

c. Pitch Coal.—Structure compact; fracture smooth, conchoidal; jointed in large angular pieces; colour brown or black; lustre waxy; does not desiccate on exposure, nor is it absorbent of water; burns freely, and contains resin disseminated throughout its mass.

II. ANHYDROUS. (*Coal containing less than* 6 *per cent. of water.*)

a. Glance Coal.—Non-caking, massive, compact or friable; fracture, cuboidal, splintery; lustre glistening or metallic; structure obviously laminated; colour black, does not form a caking coke, but slightly adheres. This variety is chiefly brown coal altered by igneous rocks, and presents every intermediate stage from brown coal to an anthracite.

b. Semi-Bituminous Coal.—Compact, with laminæ of bright and dull coal alternately; fracture irregular; lustre moderate; cakes moderately, or is non-caking.

c. Bituminous Coal.—Much jointed, homogeneous, tender, and friable; lustre pitch-like, glistening, often irridescent; colour black, with a purple hue; powder brownish; cakes strongly, the best varieties forming a vitreous coke, with brilliant metallic lustre.

SCHEDULE OF THE NEW ZEALAND COALS WHICH HAVE BEEN REPORTED ON BY THE GEOLOGICAL SURVEY DEPARTMENT.

—	Variety.	Evaporative Power.	Fixed Carbon.	Water.	Ash.	Nature of Coke.	Laboratory Number.
			AUCKLAND.				
Kaiou River, Whangaroa Harbour:— A thick seam, in green sands; collected lected by H. Williams, Esq., no mine being yet opened.	Pitch Coal	6·29	49·60	14·40	1·00	Non-caking	48
Kawakawa, Bay of Islands:— Seam 13 feet thick, in green sands; has been worked since 1865; contains much sulphur.	Glance Coal	7·44	57·20	4·60	2·20	Non-caking but occasionally adherent.	25
		7·20	55·40	4·40	1·70		27
		7·12	54·80	4·00	3·80		46
		6·14	47·30	3·20	...		...
		5·81	44.66	3·20	9·00		45b
		5·33	41·53	5·70	1·54		211
Average composition		6·51	50·15	4·18	3·04	...	...
Walton's Mine, Whangarei Harbour:— A 5-foot seam, in green sands; mined during 1865–7; contains sulphur and much ash.	Glance Coal	5·11	47·90	9·29	7·00	Non-caking	51
		4·96	38·80	7·20	12·80	,,	50
		4·71	36·80	6·10	11·90	,,	19
Average composition		4·93	41·17	7·50	10·57	...	...
Matakana:— Thin, irregular seam, in sandstone.	Brown Coal	6·20	48·96	14·15	·64	Non-caking	10

Drury:— A 6-foot seam; mined 1862–5.	Brown Coal	5·18	41·10	13·90	3·30	Non-caking	9
Waikato River, Kupakupa Mine:— A 6 to 18-foot seam, in blue and yellow clays; largely mined.	...	6·28	49·50	12·80	3·30	Non-caking	15
		5·70	45·40	17·20	1·60		47
Average composition	...	5·99	47·45	15·00	2·45	...	...
Coromandel:— Thin seam, underneath the trachyte breccias.	Altered Pitch Coal ...	6·15	47·90	7·80	11·80	Cakes slightly	1,198
Waiapu, East Cape:— Thin seam; contains much ash, being almost a shale.	Pitch Coal	4·82	37·10	2·70	35·80	Cakes slightly	88*a*
		4·68	36·02	2·98	27·37	,,	88*b*
Average composition		4·75	36·56	2·84	36·58	...	...
Mokau Harbour:— Reported to be a 7-foot seam, in an accessible position.	Brown Coal	5·04	40·00	14·00	7·80	Non-caking	49
WELLINGTON.							
Upper Wanganui River:— A thick seam reported.	Pitch Coal	6·42	51·00	8·60	4·20	Non-caking	74
	Brown coal	5·2	40·6	23·9	11·2	,,	1,291
Average composition	..	5·81	45·80	16·25	7.70	...	...
NELSON.							
Brunner Coal Mine, Grey River:— An 18-foot seam, in micaceous sandstones and grits. Half square mile has been proved, but it extends over a large area, though much faulted. Mine worked since 1865.	Bituminous Coal ...	8·10	62·37	1·99	6·20	Cakes strongly, and forms valuable coke	331
	,,	7·93	61·00	1·90	3·20		...
	,,	7·39	56·86	1·16	5·49		1,240
	,,	7·20	55·40	1·60	5·20		...
	,,	7·03	54·11	1·40	11·30		...
	,,	6·46	49·98	1·52	5·26		332
Average composition	...	7·36	56·62	1·59	6·11	...	...

SCHEDULE OF NEW ZEALAND COALS.—*continued.*

—	Variety.	Evaporative Power.	Fixed Carbon.	Water.	Ash.	Nature of Coke.	Laboratory Number.
			NELSON—*continued.*				
Mount Rochfort:—	Bituminous Coal ...	8·50	65·45	2·60	4·00		37
Seams on high plateau 10 to 18 feet thick, from 900 to 3,000 feet above sea level. Largest continuous area at Coalbrookdale, has a 10-foot seam, interbedded with quartzose and micaceous grits.	,,	8·15	62·70	1·05	4·70		329
	,,	8·09	62·29	4·99	·74	Cakes strongly and forms valuable coke	95
	,,	7·81	60·10	1·70	·40		93
	,,	7·63	58·74	·70	4·55		330
	,,	7·43	57·20	1·80	·80		...
	,,	7·36	56·63	3·01	1·29		94
Ngakawau	,,	9·25	71·16	2·31	·78		1,249
Average composition	...	8·03	63·03	2·27	2·16	...	...
Inangahua, Murray Creek:—	...	7·03	54·52	4·98	1·19	Cakes slightly	1,165
An 18-foot seam, associated with quartzoze grits.		7·02	54·94	10·38	·98		235
Average composition	...	7·02	54·73	7·68	1·08	...	...
Upper Buller, Coal Creek:—	...	6·38	50·80	19·40	7·20	Non-caking	1,096
Seam 16 feet, with brown micaceous sandstonas, found on both sides of the Buller River.		4·63	38·63	11·45	5·65		181
Average composition	...	5·50	44·71	15·42	6·42	...	..
Brighton:—	Brown Coal	5·09	41·08	21·54	10·46	,,	101
A 6-foot seam, in brown sandstone under marl.							

Mokihinui:— Brown sandstones under marls.	...	5·98	46·61	7·28	2·75	Cakes slightly	1,221
Sea Coast North of Point Elizabeth:— A 6-foot seam underneath ferruginous sandstone; good illuminating properties.	Pitch Coal	4·45	34·80	6·20	3·60	Adherent	1,220
Collingwood Mine:— Several thin seams, in brown sandstones. Mine worked since 1868.	Bituminous Coal ...	7·69	59·20	2·40	5·80	Cakes moderately	62*b*
		7·55	58·12	1·26	5·11		1,221*a*
		7·09	54·60	2·20	3·80		62*a*
Average composition	...	7·44	57·31	1·95	4·90		
Pakawau:— Same formation as the previous. Seams yet found very irregular and very variable in quality, many of them being carbonaceous shales, which are not included in the general average—no regular mining.	Bituminous Coal ...	8·71	67·00	4·90	1·40		
		6·54	50·34	3·33	10·16	Cakes	2
		6·51	50·10	3·56	8·26	Cakes strongly	522
		6·03	46·44	2·57	6·92	,,	328
						Slightly adherent	1,026
Average composition	...	6.95	53·47	3·59	6·68		
	Carbonaceous Shales ...	5·69	43·80	2·75	24·83	Cakes strongly	320
		5·35	41·20	2·20	18·90	Slightly adherent	83
		4·99	38·41	2·77	14·86	,,	102*d*
		4·94	38·00	1·60	25·20	,,	40
		4·47	34·40	3·20	40·80	,,	521
West Wanganui:— Upper part of same formation; mined since 1867	Pitch Coal	4·20	50·10	8·60	4·20	Non-caking	70*a*
		3·85	45·00	4·80	11·30	,,	
Average composition	...	4·02	47·55	6·70	7·75	...	...
Jenkins' Mine:— Irregular seam, probably in a landslip; worked in 1860; three miles from Nelson.	Jet Coal	7·94	62·40	14·40	1.80	,,	229

A

SCHEDULE OF NEW ZEALAND COALS.—*continued.*

—	Variety.	Evaporative Power.	Fixed Carbon.	Water.	Ash.	Nature of Coke.	Laboratory Number.
		CANTERBURY.					
Malvern Hill District:— Extensive, but detached, areas of Brown Coal, which, in many cases, have been altered to a valuable Steam Coal by the influence of igneous rocks, and are distinguished as Glance Coals; seams from 2 to 8 feet thick, in micaceous and argillaceous shales. Mines have been opened in Brown Coal on the Hawkins River, and in the Glance Coal on the Selwyn River and the Kowhia River; worked irregularly since 1862. The composition of the Glance Coal varies according to the proximity of the igneous rock which has affected it; seams of unaltered Brown Coal occurring 25 feet under dolerite rocks.	*a* Anthracite Glance Coal ..	11·55	89·91	3·17	7·92	Non-caking	609
	b Hard Glance Coal ...	10·33	80·01	6·50	2·54	,,	607
	c ,, ...	9·61	73·94	3·60	5·86	,,	224
	c ,, ...	9·05	69·62	2·77	12·69	,,	608
	c ,, ...	8·77	67·49	1·12	12·50	,,	1,016*c*
	b ,, ...	8.59	66·10	2·20	17·60	,,	...
	e ,, ...	8.30	64·51	6·76	7·46	,,	228
	d ,, ...	7·94	61·10	1·60	1·90	,,	...
	d ,, ...	7·72	59·39	3·84	2·94	,,	853
	d Soft Glance Coal ...	6·81	53·30	9·98	2·75	,,	1,016*d*
Average composition	...	8·87	68·54	4·15	7·42	...	...
a Acheron Valley, *b* Kowhai, *c* Hart's Mine, *d* Hill's Mine, *e* Rakaia, *f* Jebson's Mine, *g* Big Ben, *h* Craigie Burn *i* Mount Sommers, *k* Church Reserve, Selwyn.	*f* Brown Coal	5·73	46·02	21·66	5·33	,,	617
	g ,, ...	5·71	45·00	12·00	1·90	,,	...
	h ,, ...	5·62	44·62	15·54	4·58	,,	98
	f ,, ...	5·58	44·50	17·50	6·78	,,	1,016*a*
	d ,, ...	5·22	41·22	20·74	6·35	,,	1,233
	,, ...	5·05	39·60	8·80	12·40	,,	...

Malvern Hill District—continued.	*k* Brown Coal	4·99	40·12	19·50	6·15	Non-caking	618*b*
	k ,, ...	4·98	40·01	18·88	3·50	,,	1,016*b*
	k ,, ...	4·65	36·06	11·40	3·20	,,	...
Motanau, Amuri:—	,, ...	5·03	40·37	18·15	5·37	,,	107
4-foot seam.							
Average composition	...	5·26	41·75	16·42	5·55	...	...
	WESTLAND.						
Kanieri River:—	...	7·42	58·69	·86	21·11	Cakes strongly	970
Thin seams in micaceous sandstone, not thoroughly explored; contains much ash.		6·28	48·97	·29	10·82	,,	970*b*
		5·80	44·80	·40	18·40	,,	970*c*
Ross (exact locality unknown):—	...	4·01	31·43	6·58	19·46	Non-caking	1,234
Average composition	...	5·88	45·97	2·03	17·45	...	...
	OTAGO.						
North-east District, Shag Point:—	Brown Coal	5·66	45·30	19·20	5·40	Non-caking	87
Seams of Brown and Pitch Coal, with grits and sandstones. Mines open since 1862.	Pitch Coal	5·36	42·16	10·90	9·33	,,	301
	Brown Coal	5·23	41·99	19·60	5·01	,,	535
Average composition	...	5·42	43·15	16·57	6·58	...	...
North-east District, Oamaru:—	Brown Coal	5·36	43·16	21·33	10·34	Non-caking	259*a*
Thick seam, with conglomerates and pipeclays at Big Hill. (?)	,,	4·82	39·10	13·40	2·80	,,	12
Average composition	...	5·09	41·13	17·36	6·57	...	...

SCHEDULE OF NEW ZEALAND COALS.—*continued.*

—	Variety.	Evaporative Power.	Fixed Carbon.	Water.	Ash.	Nature of Coke.	Laboratory Number.
		OTAGO—*continued.*					
Green Island and Saddle Hill:—	Common Brown Coal ...	5·37	43·12	20·26	2·25	Non-caking	304
Thick seams of Brown Coal in grits and clay shale, mined extensively since 1861. Four mines at present in operation, worked by deep shafts.	,, ,, ...	5·35	42·39	14·22	2·29		305
	,, ,, ...	5·13	41·15	19·34	3·64		306
	,, ,, ...	4·86	39·28	21·01	5.65		1,146
	,, ,, ...	4·76	38·24	18·45	5·78		303
Botanic Reserve:—	Altered Pitch Coal ...	4·63	37·60	14·40	4·20	Cakes	1,085
Average composition	...	5·02	40·30	17·95	3·97	...	...
Clutha and Tokomairiro District:—	Brown Coal	6·09	48·70	20·20	3·30	Non-caking	1,114
Seams 5 feet to 20 feet, with conglomerates and sandstones. Mines worked since 1859.	Pitch Coal	5·99	46·67	7·27	10·70	,,	322
	Brown Coal	5·92	46·74	12·94	3·64	,,	309
	Pitch Coal	5·76	46·84	9·20	3·44	,,	1,144*a*
	Brown Coal	5·34	42·10	11·80	5·93	,,	313
	,, ...	5·27	41·57	11·60	5·90	,,	312
		5·26	42·15	18·69	4·58	,,	1,144*b*
		5·24	41·83	16·43	12·30	,,	307
		5·18	41·38	17·50	5·20	,,	309*c*
		5·16	41·32	16·35	4·66	,,	309*b*
		5·07	40·29	13·72	6·61	,,	313*b*
		5·01	40·02	16·10	5·61	,,	309*d*
		4·96	39·66	16·31	5·43	,,	302
		4·47	36·57	20·91	7·32	,,	1,145*b*
Average composition		5·34	42·56	14·93	6·04	...	...

SOUTHLAND.

Imaka, Catlin's River:— Thin, irregular seam, in sandstone.	Semi-bituminous	7·72	59·40	4·20	1·40	Cakes	1,000
Waikawa:—	,,	5·69	44·34	6·60	16·11	Slightly coherent	326
Irregular seams, in coarse sandstone.	,,	4·94	38·91	10·32	10·00	,,	230*a*
Mount Hamilton:— Irregular seams, in sandstone.	Bituminous	6·38	49·08	1·68	9·50	Cakes strongly	1,105*a*
Seaward Downs:—	...	6·45	49·61	8·06	7·25	Slightly coherent	1,264
Average composition	...	6·24	48·27	6·17	8·85	...	...
Wairaki District:—	Brown Coal	6·10	48·30	15·60	5·10	...	71
Seams 4 to 10 feet of Brown and Pitch Coal, in micaceous sandstones and clays.	,,	5·24	41·78	16·67	4·88	...	197
No regular mines opened.	Pitch Coal	4·79	37·81	10·94	2·97	...	235
	,,	4·55	36·01	11·33	12·45	...	200
	Brown Coal	3·51	28·44	15·33	6·22	...	200*b*
Orepuki:—	,,	5·44	43·20	14·90	2·80	...	77
Same formation as above. Average composition	...	4·94	39·26	14·13	5·74	...	...
Preservation Inlet:—	Glance Coal	8·63	66·43	4·40	2·24	Dull, non-caking	324
Thin, irregular seams, in sandstone, on Coal Island, much faulted and altered.	,,	8·03	61·83	4·40	5·14	...	323
	,,	7·07	54·38	4·20	11·20	...	325
Average composition	...	7·91	60·88	4·33	6·19	...	...
Preservation Inlet:—	Pitch Coal	5.62	43·83	6·58	6·67	Non-caking	176
Thick seams of Brown and Pitch Coal on the main land, south of Coal Island.	Brown Coal	5·17	41·23	16·20	7·24	...	148
	,,	4·85	38·87	17·77	3·87	...	234
Average composition	...	5·21	41·31	13·52	5·93	...	...
Tuapeka:—	...	4·28	34·40	16·80	4·40	...	243
Thick seam of lignite under the Pliocene gold-drift; shows vegetable tissue.							
Waitahuna:—	..	4·71	37·25	11·06	11·81	...	308
Similar formation.							

SYNOPSIS OF THE YOUNGER FORMATIONS OF NEW ZEALAND,

BY F. W. HUTTON, F.G.S.,
ASSISTANT GEOLOGIST.

November 5th, 1872.

The following synopsis is based on an examination of the tertiary, and upper secondary, marine fossil Mollusca, in the Colonial Museum, of which I have been able to determine 400 species. The reasons that have induced me to suggest this classification will be given when the descriptions of the fossils are published; but as that cannot be done for some time it has been thought desirable that this synopsis should be communicated at once.

CAINOZOIC EPOCH.

PLEISTOCENE PERIOD.

Number of species determined	... ...	... 82
„	of recent species	... 71
„	that pass down into the Whanganui Group	... 48
„	confined to this formation ...	... 4
Per centage of recent species	... ...	... 86

Localities.

North Island.—Whanganui (upper series); Cape Kidnappers (north-west side).

South Island.—Motanau, Canterbury.

PLIOCENE PERIOD.

Newer Pliocene, or *Whanganui Group.*

Number of species determined	... ...	... 89
„	of recent species	... 68
„	that pass up into the Pleistocene formation	... 48
„	that pass down into the Awatere group	... 29
„	confined to the group	... 8
Per centage of recent species	... ...	... 76

Localities.

North Island.—Shakespeare Cliff, Whanganui; Patea.

South Island.—None known.

MIOCENE PERIOD.

Upper Miocene, or *Awatere Group.*

Number of species determined	... ...	... 95
„	of recent species	... 39
„	that pass up into the Whanganui group	... 29

Number that pass down into the Kanieri group ...	26
„ confined to the group	29
Per centage of recent species	41

Localities.

North Island.—White Cliffs, Taranaki; Upper Whanganui River (Paparoa, Parakino, &c.)

South Island.—Port Hills, Nelson; Conway River; Mt. Caverhill, Nelson; Awatere; Motanau, Marlborough; Mt. Cookson; Awamoa.

Lower Miocene, or *Kanieri Group.*

Number of species determined	48
„ of recent species	12
„ that pass up into the Awatere group ...	26
„ that pass down into the Hawke Bay group ...	13
„ confined to the group	13
Per centage of recent species	25

Localities.

North Island.—None known.

South Island.—Kanieri and Callaghan's Creek, Westland; Kokohu; Lyndon; Lower Gorge of the Waipara; Waikari, Canterbury.

OLIGOCENE PERIOD.

Upper Oligocene, or *Hawke Bay Group.*

Number of species determined	55
„ of recent species	11
„ that pass up into the Kanieri group	13
„ that pass down into the Waitemata group ...	11
„ confined to the group	21
Per centage of recent species	20

Localities.

North Island.—Napier; "The Taipos," Castle Point, Waitotara, Wellington.

South Island.—Hurunui Mound, Nelson; Trelissick (upper series) Canterbury; east side of Te Anau Lake, Otago.

Lower Oligocene, or *Waitemata Group.*

Number of species determined	26
„ of recent species	6
„ that pass up into the Hawke Bay group ...	11
„ that pass down into the Ototara group ...	11
„ confined to the group	6
Per centage of recent species	23

Localities.

North Island.—Waitemata, Kawau, Cape Rodney, Auckland.

South Island.—Trelissick (lower series), Canterbury; Waitaki, Limestone of Lake Wakatipu, Otago.

EOCENE PERIOD.

Upper Eocene, or *Ototara Group.*

Number of species determined	... ...	43
„ of recent species ...	... ...	4
„ that pass up into the Waitemata group	...	11
„ that pass down into the Waipara formation	...	1
„ confined to the group	... ...	25
Per centage of recent species	... ...	9

Localities.

North Island.—Raglan, Whangape Lake, Poverty Bay, Auckland; Cape Kidnappers, Hawke Bay.

South Island.—Tata Island, Takaka, Cape Farewell, Brighton, Kaipuke Cliffs, Nelson; Black-birch Creek, Weka Pass (upper series of Mt. Brown), Curiosity Shop, Canterbury; Oamaru, Caversham, Winton, Waimea Plains, Castle Rock, River Waiau, north side of Mt. Hamilton, Otago.

MESOZOIC EPOCH.

CRETACEOUS PERIOD.

Danien, or *Waipara Formation.*

Number of species determined	... ...	24
„ of recent species	... ...	0
„ that pass up into the Ototara group ...	...	1
„ that pass down into the Kawhia beds	...	1
„ confined to the formation ...	... ...	21

Localities.

North Island.—None known.

South Island,—

(*a.*) *Greymouth Group*—Cobden, Brunner Coal Mine, Mokihinui, Culverden, Nelson.

(*b.*) *Malvern Hill Group*—Boby Creek, Waipara; Weka Pass; Selwyn and Hororata Rivers, Malvern Hills, Canterbury.

(*c.*) *Amuri Group*—Amuri Bluff, Marlborough.

The evidence is not yet sufficient to show whether these three groups are synchronous or not, but they are closely related to each other.

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Geological Survey of New Zealand.

REPORTS

ON

GEOLOGICAL EXPLORATIONS

DURING 1871-2,

WITH MAPS AND SECTIONS.

JAMES HECTOR, M.D. F.R.S.,
DIRECTOR.

PUBLISHED BY COMMAND

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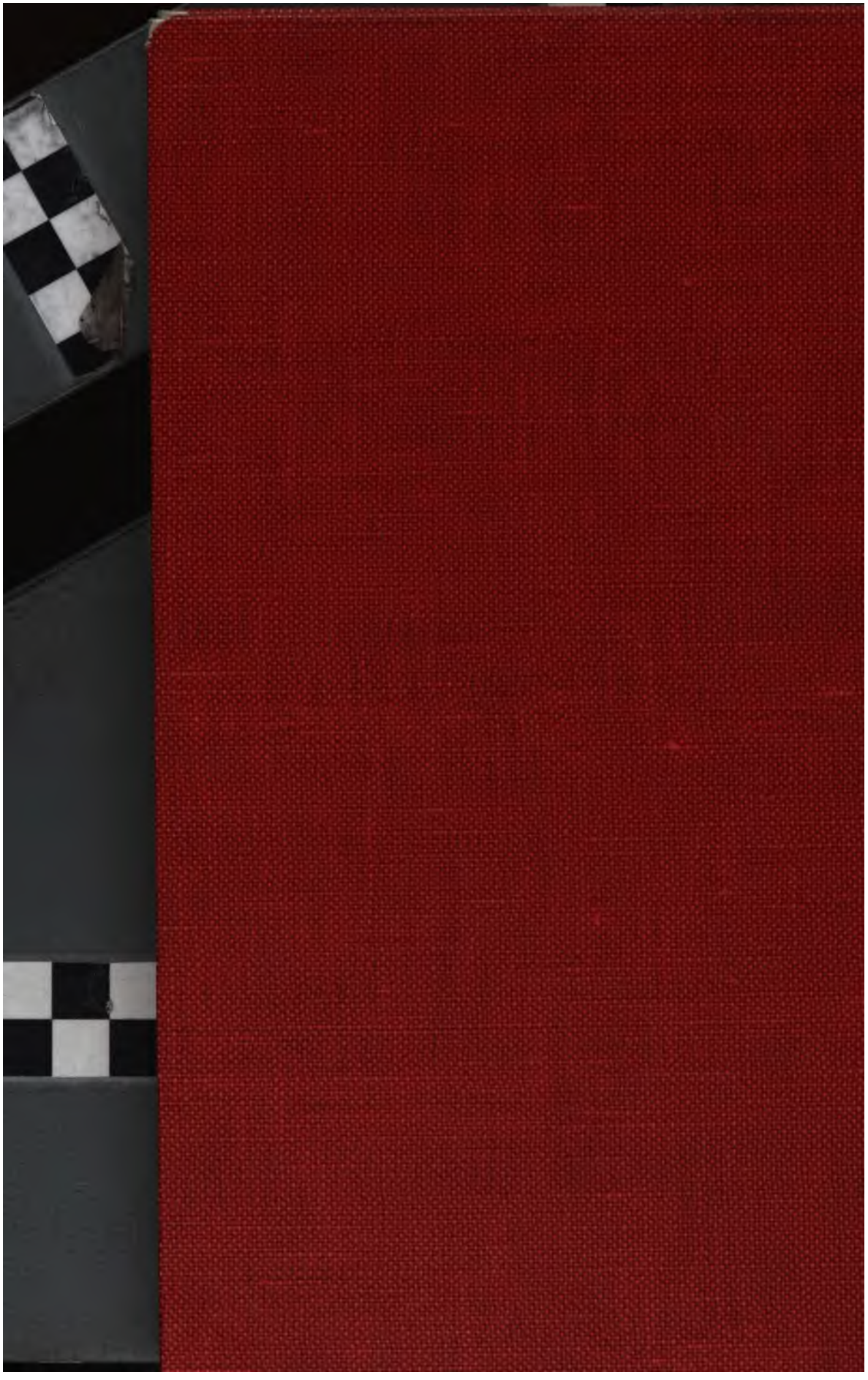
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